Smallholder farmer perceptions on the Climate Smart Agriculture (CSA) practices in Bihar, India

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Summary

Climate Smart Agriculture (CSA) is a recent concept launched by the FAO. It promotes technologies that increase productivity, promote resilience to related climate hazards and risks and contribute to climate change mitigation whenever possible. So far, previous research on CSA programs has mainly centered on case studies across the globe, surprisingly there are no agreed indicators to measure effectiveness. On the other hand, technology adoption is a widely studied topic that has given insights into different type of constraints. This study aimed to analyze the smallholder farmer and researchers perceptions of importance, effectiveness and adoptability of CSA and associated technologies and practices. Secondly, it aimed to assess the farmer context to design suitable farm scenarios with another MSc. Thesis project. It focused on the farmers, who are ultimately the end-users of the technologies. Therefore, 25 male farmers in Bihar (India) that were acquainted with the CIMMYT CSA program were interviewed. A questionnaire was designed to assess farmer objectives, constraints, and adoption of CSA Technologies (CSAT), and perceptions of climate change. In addition, Fuzzy Cognitive Mapping (FCM) inquired CIMMYT experts' perception on CSAT benefits and constraints.

Results show that farmers aim at ensuring household food security and productivity. Regarding CSAT adoption, farmers perceive benefits on productivity and resilience. They also face constraints such as limited resources (e.g. land, capital, facilities, irrigation, machinery), performance-related shortcomings (e.g. lack of seed control, low accuracy in weather services) and low knowledge and skills (e.g. operating machinery, crop rotation suitability). Climate change is seen as a present and future challenge. Farmers described changes in use of land, increase in maize and decrease in rice cultivation, increasing temperature throughout the year, late start of seasons. In addition, they reported that 49 and 39 percent of their land is fallow in the Kharif and Zaid cropping seasons due to low moisture in soils and changing raining patterns

As future options, farmers considered to have more cash crops or escape crops (e.g. mango, tobacco, vegetables), and wanted to adopt agricultural technologies or practices. Some farmers mentioned they would quit farming or initiate other economic activities and keep their off-farm/on-farm income balance. When asked about support from CIMMYT and BISA, farmers proposed topics that are beyond the CSAT offered by these institutes. On the other hand, in the FCM created by CIMMYT staff, main constraints related to machinery availability, capital investment, small-land holding sizes, knowledge gaps, high input cost and seed availability. Reported benefits were associated to productivity, resilience and mitigation.

This case study was a first exploratory one that integrated smallholder farmers as a main source of information and contrasted that to expert views. Farmers perceive climate change, they are adopting CSAT but they face multiple constraints that hinder successful outcomes. Implications of how these constraints are present in Samastipur are discussed. Limitations of this study were covering a small number and only male farmers who were already part of a CSA initiative; using a new questionnaire mixed with a new learning experience made data collection challenging at the beginning; suitability of FCM to assess constraints and objectives. Recommendations are made to use more participatory dynamics and strengthen cooperation with other local institutes to address farmers' needs. Future research needs to include female farmers. There are opportunities to share Farm Design model through learning workshops with farmers at it can be an educational tool to support decision making processes.

1 Introduction

The Climate Smart agriculture (CSA) concept was proposed by the Food and Agriculture Organization of the United Nations (FAO) at the Hague Conference on Agriculture, Food Security and Climate Change in 2010. It built upon three pillars: increase agricultural productivity and incomes, adapt and build resilience to climate change within the agricultural systems, and reduce GHG emissions when possible. Through CSA programs, promotion of different technologies, practices and policies involve diverse institutions and investments. These interventions take place at field, farm, regional or national level (FAO, 2012). CSA case studies reveal numerous and varied limitations at policy level and at large scale projects (Cooper et al., 2013) as well as per areas of intervention (Dinesh et al., 2015). In addition, there is a global research agenda for CSA technologies. For instance, improved wheat and maize varieties that are drought-resistant; legumes as Nitrogen (N) fixers for mitigation and adaption options and for less N-input reliance; manure use for N-efficiency in farming systems and Conservation Agriculture are leading developing countries interventions (Steenwerth et al., 2014). Strikingly, the measurement of CSA programs effectiveness is not standardized as the concept is relatively new and it includes a wide diversity of food system/rural livelihood practices and outcomes. So far in research, there is only a protocol to do a systematic review of the CSA programs. The proposed CSA indicators for productivity consider changes in yield, income and food security. In resilience-related CSA indicators are biophysical aspects such as biodiversity, soil resources, economic features of input efficiency and labor, and social aspects of gender balance workload. Mitigation CSA indicators comprise GHG emissions, emission intensity, carbon stocks and fuel consumption (Rosenstock et al., 2016). An approach that looks into technology adoption limitation from a climate change adaption can give insights to sort out the limitations and provide guidelines to measure effectiveness.

The aim of this thesis was to explore farmers' objectives and constraints when adopting CSA technologies and to integrate the findings into a farming systems modelling tool (Farm Design) to design suitable farming scenarios for smallholder farmers. This thesis topic was part of a research project between CIMMYT-India (World Centre for Research in Wheat and Maize, with the project location in Bihar, Northern India) and Wageningen University (The Netherlands). This thesis was partnered with another one that assessed the technical feasibility and impact.

This study addresses the following research questions:

1. What are farmers' visions on the future of farming and the effects of climate change (and associated risks)?
2. What are long-term objectives and how are aspects of climate smart agriculture (enhanced productivity, adaptation and mitigation) integrated?
3. How can these be transformed into technical objectives and/or constraints for Farm DESIGN?
4. What is the role of research and extension organizations like CIMMYT & BISA from the farmers' perspective? Moreover, how are they able to support the CSA practice adoption?
5. How do farmers perceive the generated solutions and the practices that are proposed? What are the main constraints?

1.1 State of research

1.1.1 Technology adoption: interaction of different aspects

Diffusion of innovations has been addressed for nearly 60 years now (Rogers, 2004). In agriculture, different types of technology adoption constraints have been identified. A distinction has been made between the pre-requisites or exogenous conditions for adopting new agricultural technologies (e.g. a certain land holding size necessary for mechanized management) and the endogenous variables that characterize the specific technology (e.g. a new tilling practice with different machinery accessories that improves carbon flow and lowers emission rates) can facilitate the adoption process (Sumberg, 2005). Recently, a framework addressing CSA technologies adoption limitations for Europe has identified different aspects such as economic, institutional/regulatory, psychological, organizational, consumer/market and social, highlighting the complexity of technological change (Long, Blok, & Coninx, 2016). For this thesis research project, limitations related with the adoption of agricultural practices or technologies that were encountered in the literature, were classified in three aspects: human, contextual, and technological (

Figure 1. Classification of factors that limit the adoption of agricultural technologies.

). These limitations can combine making adoption a complex problem to solve. Interdisciplinary research is expected to contribute to the design of suitable agronomical alternatives for farmers in such complex situations.

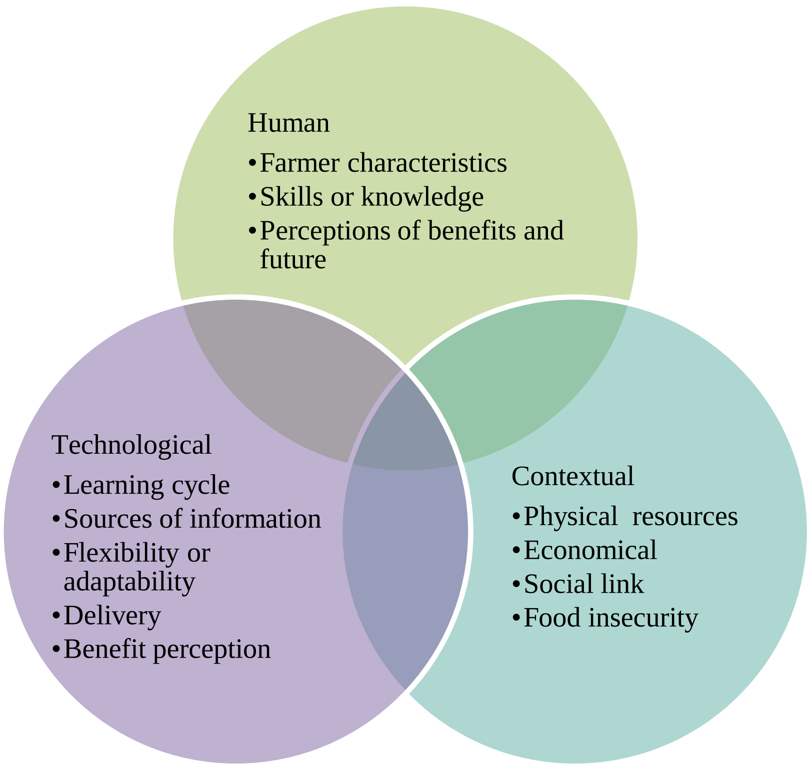

Figure 1. Classification of factors that limit the adoption of agricultural technologies.

As shown in Figure 1, human factors are understood as characteristics of farmers such as age, gender, income, education level (Kasirye, 2010; Peterson, 2014), perceived benefits and view of the future (Giller, Cadisch, & Palm, 2002; Giller, Witter, Corbeels, & Tittonell, 2009; Leeuwis & Ban, 2004), lack of awareness or knowledge (Kuivanen, K., Alvarez, S., Langeveld, 2015; Vignola, Koellner, Scholz, & McDaniels, 2010) or willingness to adopt new technologies based on past experiences (Leeuwis & Ban, 2004). By contextual factors, physical resources, for instance, water availability, land tenure status or land holding-size (Kasirye, 2010; McCarthy & Brubaker, 2014), product competition with other uses such as livestock feed or fuel (Giller et al., 2009), food insecurity (Jerneck & Olsson, 2014) and economic constraints (Peterson, 2014). Specifically, at farm level, there are costs associated with the sustainable land management practices' adoption such investment costs, recurrent expenses, opportunity, transaction and risk costs, giving an idea of the trade-offs that farmers face (Mccarthy, Lipper, & Branca, 2011). In addition, infrastructure and connection by roads and markets are well-known challenges for rural and agronomical development. Social aspects are understood as the type and strength of links with agricultural extension and/or political organizations, which could support or not the adoption of a new technology (Dinesh et al., 2015; Kilelu, Klerkx, Leeuwis, & Hall, 2011). Technology factors are associated to the instrument or practice per se, which are mentioned as endogenous conditions (Sumberg,

2005) or selective factors (Leeuwis & Ban, 2004). They make a technology suitable for a determined type of user and ultimately this influences the adoption rate. Adoption is regarded as a process in which people request different types of information as they are learning the new technology (Leeuwis & Ban, 2004). Interestingly, participation of end-user in the design of technologies facilitates adoption (Long et al., 2016). A current discussion is the fact that technology use is interrupted when programs or subsidies schemes associated with it end (Halbrendt et al., 2014; Steenwerth et al., 2014). Therefore, approaching technology adoption as an interactive process between human, contextual and technology factors serves to identify adoption barriers appropriately. This thesis assumes that adoption is no a unidirectional top-down process but it is influenced by the interaction of the former factors.

1.1.2 A framework that links climate change adaptation with CSA technology adoption

Climate change adaptation can take place at local, regional or global levels by involving different groups of actors. As a framework to understand farmers perception, the Model of Private Proactive Adaptation to Climate Change (MPPACC) explains how climate change adaptation varies amongst people (Grothmann & Patt, 2005). According to this model, there are two aspects that influence adaptive behavior: risk appraisal (acknowledging the threats and potential damages: the probability and the severity) and adaptation appraisal (acknowledging the ability to take action and the associated costs). This will result in two types of actions: adaptation (those actions that prevent damage) and 'maladaptation' (avoidant reactions). There can be a low adaptive capacity, that is when people want to adapt but do not have enough resources. In addition, it proposes that social discourse influences people's perception (agents that influence this are: media, friends, neighbors, public agencies). As motivational aspects, there are incentives that promote adaptive behavior (Grothmann & Patt, 2005). Additionally, information sources consulted by farmers for climate adaptation relate to farmers social identity and cooperatives' roles (Frank, Eakin, & Lopez-Carr, 2011).

As an example, adaptation measures at farm level, are evidenced in the way a farmer changes their operations, e.g. selecting different crops, incorporating new technologies; by developing new networks to seek more resources or information, e.g. joining cooperatives, consulting extension services or NGO's; by changing farm income, e.g. diversifying income, starting or increasing more off-farm income. An analysis of farmer perception of climate change in Maharashtra (West India) and Andhra Pradesh (South East India) found different adaptation measures such as changing crop selection from food crops to vegetable and commercial crops.

As well as incorporation of irrigation technologies such as farm surface ponds, furrow channels, ditches and check-dams (Banerjee, 2014). Similarly, in Tamil Nadu, South India, an assessment was made of climate change perception and changes in farmers cropping systems (Dhanya & Ramachandran, 2015). In order to face changes in monsoon rains and temperature changes, the adaptation strategies were switching to short duration crops such as pulses, vegetables, flowers. Proposed alternatives included as building small check dams in the nearby rivers, conserving the existing farm ponds, changing crop calendar, diversifying income, crop weather insurances and early weather waring systems (Dhanya & Ramachandran, 2015).

As this study focuses on CSA technologies, a model was developed to explain CSA adoption as a means to respond to climate change, using the MPPACC as a reference (Figure 2). Local resources, current challenges and personal expectations are factors that determine farmer objectives and constraints. As an adaptation response, farmers could adopt CSA technologies. Afterwards, if there are perceived benefits, there will be a CSA reinforcement which results in continuing with the CSA technology and can also consider and adopt more CSA technologies. However, if there are perceived constraints, there will be a CSA rejection or partial adoption, some CSA technologies may be abandoned or other alternatives may be considered. This model includes the underlying assumption that farmers are decision makers and balance their trade-offs. Secondly, it assumes that experience will determine CSA engagement.

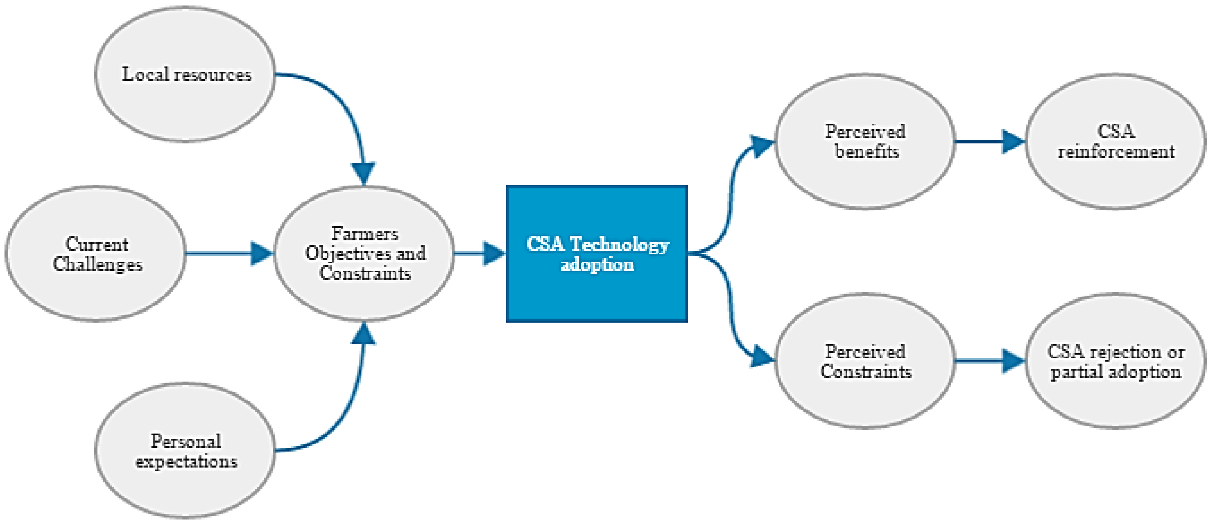

Figure 2. Author’s model of CSA Technology adoption and farmers objectives, constraints and its reinforcement or rejection.

2 Methods

As mentioned earlier, two theses were combined to explore CSA solutions for smallholder farmers in Bihar. Figure 3 shows an overview of how these were structured, the present thesis carried out the social approach to assess farmer objectives and future views, perceptions on CSA technologies and climate change through a questionnaire. The design of the structured questionnaire considered similar scientific articles, field constraints and project set-up. Fuzzy Cognitive maps (FCM) with CIMMYT experts were used to complement the understanding of farmers' context. A feedback meeting was carried out with farmers to confirm the most relevant constrains and objectives for the modeling of farming scenarios.

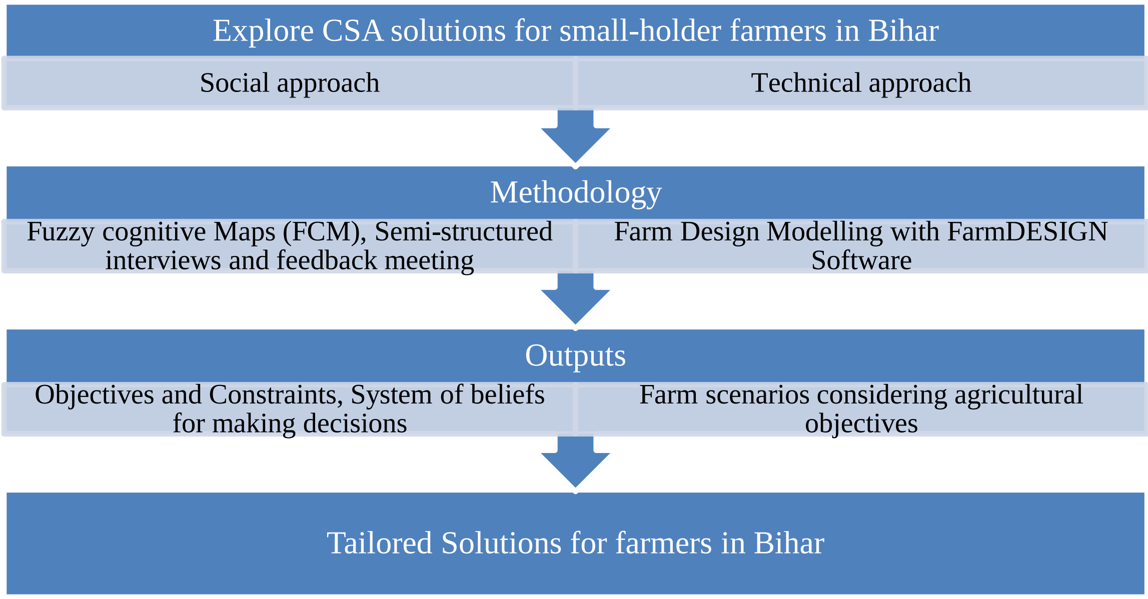

Figure 3. General outline of joint thesis project.

2.1 Participant selection and data collection

CIMMYT had given a typology consisting of five farmer types (Resource poor worker, Mixed-livestock and crop, Part-time, Small-vegetable, Well-endowed) with the following criteria: land size, percentage of on-farm and off-farm income, percentage of crops that were sold to the market, number of livestock heads, percentage of milk that goes to the market, land ownership, mechanization level (Frelat, Lopez-Ridaura, Jat, Valbuena, & Van-Wijk, 2015). For further details see: Annex 2- CIMMYT farm typology description. Five farmers of each type were interviewed, resulting in a total of 25 farmers. This number was chosen considering theoretical saturation point. In qualitative research, this occurs when a stable number of interview codes or meanings is reached after a number of interviews and when additional participants do not add new significant information. Determination of the saturation point varies within the research scope and requires expertise from the interviewer (Guest, Bunce, & Johnson, 2006). Although there were 25 farmers, the typology approach indented to investigate differences between farmer types. In addition, as there was only one student and one translator carrying out the fieldwork this number was convenient. Previously CIMMYT selected the farmers; men farmers who already knew the staff and/or on-farm trials in the area. In total four PhD experts in crop and plant science and the CIMMYT director for Asia participated in FCM. Data collection took place between February-April 2016 in Samastipur (Bihar).

2.2 Farmers questionnaire

A structured questionnaire assessed farmers' objectives, constraints, CSA adoption, views on challenges and climate change. Consultation of several scientific articles served for question types, possible data analysis and general findings in these areas of research. Content analysis was the information analysis method, it grouped farmers answers categories and counted frequency amongst all answers to highlighting most repetitive topics. In qualitative research, this methodology facilitates the identification of meaningful information across interviews (Harwood & Garry, 2003). In addition, by grouping answers, a general overview of results was possible in the field and this facilitated the feedback session design. By creating answer categories, meaningful differences and critical topics could be easily detected among farmer types. Triangulation of information between the farmers and CIMMYT staff supported a complete assessment in order to contrast similarities and divergences of different stakeholders (Rifkin & Pridmore, 2001).

The questionnaire was organized in five sections (Annex 1- Questionnaire for farmers) containing open and closed questions. A brief explanation follows:

1. Demographic and cropping system information: A standard template from Farming Systems Ecology Group from Wageningen University. In addition, there were questions about crop and livestock products and the percentage going to market. This facilitated to confirm the farmer typology and have an overview of the farms activities.
2. CSA Technologies use, benefits and constraints: Exploration of incorporation and perception of major benefits and constraints. Some question items were taken from a case study that evaluated CSA technologies in Colombia (Peterson, 2014).

3. Challenges and future vision: Asking farmers about their challenges without directly referring to climate change to understand the complexity of constraints that may hinder risk appraisal (Frank et al., 2011; Mertz, Mbow, Reenberg, & Diouf, 2009; Tucker, Eakin, & Castellanos, 2010).
4. Choosing crops according to variables: Changing cropping patterns is one of the adaptations that farmers have to face climate change (Banerjee, 2014; Dhanya & Ramachandran, 2015). Nevertheless, different aspects can motivate a change, therefore different questions regarding the impact of market price, seed cost, income, larger household, labor availability, social pressure, climate and nutrients were included. Ideas were taken from a case study in Nepal (Halbrendt et al., 2014).
5. Climate Change: Research on farmers perception include questions regarding changes in rainfall patterns (amount, frequency) start and end of planting seasons, temperature changes (Traore et al., 2015). Adaptation to climate change questions include past farming activities, observed changes, future strategies (Nguyen et al., 2016).

CIMMYT staff reviewed an initial questionnaire, then a trial with three farmers followed to make final adjustments. There were twenty-five interviews with three hours duration each (considering the translation time). Farmers gave oral consent of participation at the beginning of each interview and it marked on the interview papers. All participants approved their participation in the research.

2.3 Fuzzy Cognitive Maps

Fuzzy Cognitive Mapping (FCM) with CIMMYT staff was conducted to assess the perception on the benefits and constraints of CSA Technologies. FCM is a parameterized and semi-quantitative concept mapping technique that illustrates a belief system (Halbrendt et al., 2014; Kok, 2009). It is sustained that FCM "does not make quantitative predictions but rather shows what will happen to the system in simulations under given conditions of relationships" (Özesmi & Özesmi, 2004, p. 47). This approach has been used in different fields such as electrical engineering, medicine, political science and ecology (S. A. Gray, Zanre, & Gray, 2014; Kok, 2009). FCM consists of defining concepts that represent as elements in the system. These elements relate through causal relationships: the out-flowing or in-flowing interactions are marked with numbers ranging from 0 to 1, punctuating the strength of the influence that a concept has on another concept within the system. Positive (+) and negative (-) signs indicate an excitating or inhibitory relationship. This model is based on graph theory and it is a standard vector calculation; a sensitivity analysis can be run once the map is stabilized to detect which weighting factors are important (Kok, 2009)

Other important aspects of the FCM are: number of concepts and connections and whether these differ between the stakeholders; number of receivers (concepts that are influenced but do not influence others); number of transmitters or drivers (concepts that have forcing variables but are not influenced by other variables); ordinary (concepts with both transmitting and receiving functions); centrality (absolute value of either overall influence in the model or the influence of individual concepts, showing influence in the whole system or the importance of one concept. The higher the value is, the greater the importance); complexity (ratio of receiver variables to transmitter variables, higher complexity indicates more complex system thinking); density (number of connections compared to number of all possible connections. The higher the density, the more potential management polices exist); hierarchy index (indicates hierarchical to democratic view of the system; top/down is 1 or democratic perception is 0 of the mental model) (S. A. Gray et al., 2014).

The benefits of FCM are that it supports group decisions by illustrating how concepts (representing system features and/or processes) interact with each other and facilitate targeting those that are the critical to achieve a desired goal. On the other hand, the main limitations of this approach are that creating scenarios carries assumptions, and therefore uncertainties and potential inconsistencies can still be present. Thus, the process for creating such maps becomes crucial. Nevertheless, FCM allows to integrate diverse knowledge with varying depth (Özesmi & Özesmi, 2004). Several weaknesses have been identified in FCM such as: degree of understanding systems dynamics when stakeholders draw the maps; focusing on the numbers can distract the process and that it is a time consuming process (Kok, 2009).

Fuzzy Maps can be obtained from questionnaires and also through interviews with people who create them directly (Halbrendt et al., 2014; Özesmi & Özesmi, 2004). Therefore, the procedure to obtain the FCM consisted of a workshop in which CIMMYT experts answered these questions: “How do the agronomic innovation influence productivity and climatic resilience?” and “How can farmers cope with current constraints?” An explanation of the aspects and purpose of using FCM opened the section, a group brain storming activity to identify different elements and driving forces followed it, and then experts worked in pairs to create a FCM. The FCM were processed with Mental Modeler software (Steven A. Gray,

Gray, Cox, & Henly-Shepard, 2013). After recollecting this data, a final FCM took as inputs: (1) results from the farmer's questionnaire, (2) maps made by different technicians analyzing specific and general CSAT and policy aspects, (3) feedback from the farmers meeting. Due to literacy constraints FCM was not used with farmers directly. For this reason, certain questionnaire items aimed to provide input for drawing the relationships.

2.4 Feedback session

A feedback session at the end of the data collection validated the most relevant constrains and objectives for the modeling of farming scenarios. It also discussed FCM concepts and driving forces. To design this farmer workshop a positive inquiry approach was used as a reference (Cooperrider, Whitney, & Stavros, 2008). By sharing findings from the survey with farmers, this activity aimed to 'discover' the positive aspects of the farms in Bihar and to raise awareness on how the future alternatives can be co-constructed and sustained.

2.5 Study Area and CIMMYT CSA program

Bihar is located in North India, between 24º20'10" and 27º31'15" N latitude and 82º19'50" and 88º17'40" E longitude as shown in Figure 4. Altitude of the state is approximately 53 m above sea level. It is a tropical and sub-tropical region. Bihar is part of the eastern Indo-Gangetic Plains (IGP), which are characterised by rice-wheat-maize cropping systems. When compared to the western IGP, the east region has less agricultural development with lower crops yields. Its characterized by smaller-holding farms, crops dependant on monsoon rains and less irrigation technologies (Taneja, Pal, Joshi, Aggarwal, & Tyagi, 2014). Bihar is the third largest populated state in India, literacy rate is close to 62 percent (Census Population 2015 Data, 2011). Ca. 90 percent of the population resides in rural areas (CIMMYT, 2015). Nearly 90 percent of the operational holdings in Bihar are either marginal, which is below one hectare (ha) or small-holding, between 1- 2 ha. (Center, 2014). This state is the third largest vegetable producer and seventh fruit largest producer in India; the agricultural sector contributes to one-fourth of the State's Gross Domestic Product and employees nearly 80 percent of its population (Salam, Anwer, & Alam, 2013).

Two villages in Samastipur district were selected for this study, Digmbra with coordinates 25°53.567 and 085°40.023, Kuboli at 25°54.387 and 085°38.868 as shown in Figure 5. As seen from above there are greener areas in Kuboli this is due to the presence of mango orchards. Average amount of rainfall during monsoon in Samastipur is of 1016 mm, it presents 42 average rainy days during monsoon, and maximum rainfall of a day during monsoon is 123 mm. A significant increase in mean temperature has been observed in PUSA station during the last 45 years, minimum temperature during winter has varied between zero to 7°C while maximum temperature for summer has been from 37 to 46 °C, there has been a decreasing trend in days with extreme minimum temperature, meaning an increase in night temperatures during winter. In general, Bihar region has seen increasing temperature during the last decades and extremes of temperature have changed accordingly (Chhabra & Haris, 2015). Flooding in northern Bihar is caused by flat landscape and as 80 percent of concentrated rainfall happens between July and September (CIMMYT, 2015).

Figure 4. Location of Bihar in India.

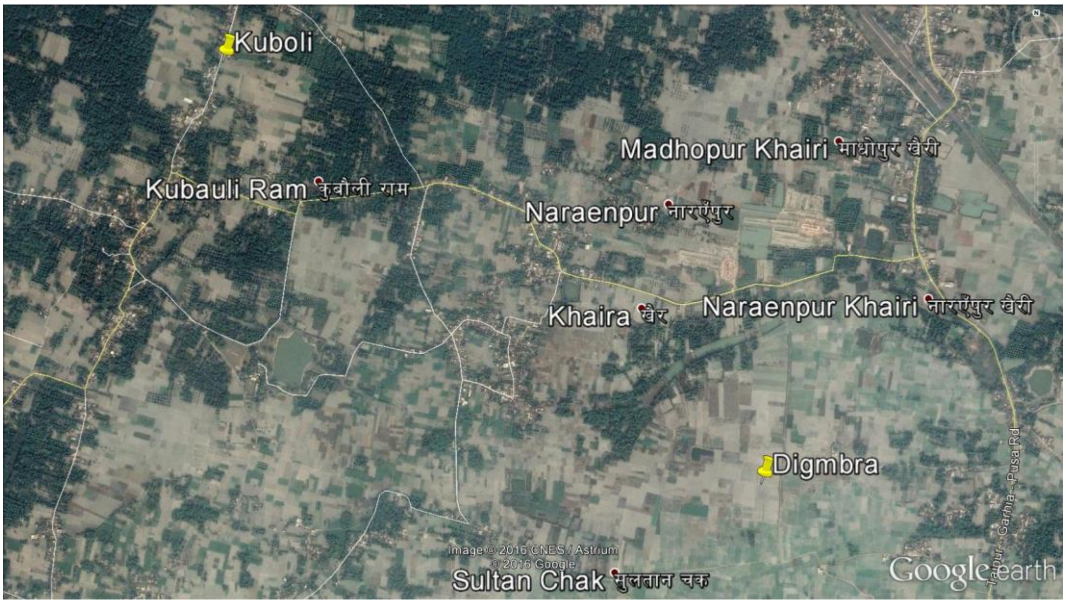

Figure 5. Landscape view of Kuboli and Digmbra.

The two selected villages are located in the agro-ecological zone North West alluvial plains (Zone 1) presenting mostly sandy loam and loam soils. 86% of this zone has irrigation, main cropping systems are Rice-Wheat, Maize-Wheat, Maize- Arhar, Maize-Potato-Mung Bean, Maize- Sweet Potato-Moong, Maize- Mustard-Moong, Rice-Potato-Maize, Rice-Sugarcane (Salam et al., 2013). Specifically, Table 1 shows a summary of the major crops and cropping seasons specific for the two villages, using inputs from CIMMYT experts.

Table 1. Cropping seasons and major crops in Samastipur.

Season	Kharif (Monsoon)	Rabi (winter)	Zaid (spring)
Months	June to end-September	October to March/April	March to June
Major crops	Rice, maize, pigeonpea, sugarcane, fodder jowar and vegetables	wheat, chickpea, lentil, maize, potato, rapeseed- mustard, tobacco	Muskmelon, watermelon, gourds, mungbean, maize

2.5.1 CIMMYT CSA program antecedents

With the support of CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), CIMMYT has introduced the concept of 'Climate Smart Villages (CSV)' which is based on the CSA pillars. It covers specific technologies that focus on water, carbon, nutrient, energy and weather (Table 2). The different CSA practices have been selected because they have shown advantages in aspects like yield, profitability, soil fertility and stability to face climate change (Frelat et al., 2015; Jat et al., 2014). The diffusion of these technologies has been done by setting farm trials and strengthening partnerships between academia, business and United Nations (UN) agencies (CIMMYT, 2013). In Bihar these CSV have been part of several activities since monsoon 2012 and during winters of 2013-2014 in Vaishali and Jamui district. The identification of constraints with the farmer community consisted of a series of meetings between August- September 2012 to January-May 2013, in which 730 farmers participated from three villages in the Rajapakar block. The testing in the farmers plot consolidated the rice plots so that machinery usage was possible. Meaning that neighbors were growing crops together in one consolidated plot so Direct Seeded Rice machinery could enter (some farmers have quite small like 200 m^2). Regarding dissemination of technologies, one women farmer group formed to buy a zero tillage machine and use it for their own crops and to rent it out to their community. CIMMYT reported four different initiatives: (1) service provider creation and training, (2) training of public agricultural officials, (3) private-public partnership establishment, (4) farmers 'group creation. These groups promoted Zero Tillage (ZT) wheat, Direct Seeded Rice (DSR), maize bed planting, pigeon pea, Green Seeker and Nutrient expert technologies (Aryal, Jat, Singh, Gehlawat, & Agarwal, 2015; CIMMYT, 2013, 2015).

Table 2.CIMMYT's CSA Technologies outlined by scope area

Scope and CSA Technology	Description
Water Technologies	Technologies that minimize water requirements and improve yields.
Land Laser Levelling	Mechanised land levelling with a laser leveller.
Direct Seeded Rice	Directly seeding rice on field without inundating, saving transplant and nursery time.
Crop Diversification	Introduction of different crops to diversify income, e.g. maize, mung bean.
Weather Technologies	Technologies that improve weather management and minimize risks.
Agronomical Weather Services	Information provided on weather forecast from local weather stations.
Stress tolerant seed varieties	Wheat, rice and maize improved varieties that are being introduced.
Irrigation schedule for wheat	Education on optimal irrigation dates for wheat crop.
Agroforestry	Planting trees to optimize cropping areas, diversify income and balance water requirements.
Nutrient Technologies	Technologies that promote nutrient efficiency through minimizing inputs, improving nutrient cycle management.
Nutrient Expert decision tools	Software application that calculates the needed fertilizer to balance crop requirements.
Green Seeker Crop Sensor	Handheld crop sensor to assess vigour of a crop, giving recommendations on fertilizer requirements.
Residue Management	Incorporating crop residues into the field to increase soil carbon, fibber and nutrients.
Legume catch-cropping	Diversifying cropping systems with legumes for household income and consumption and provide nitrogen to soil.
Conservation Agriculture	Continuous minimum mechanical soil disturbance, permanent organic soil cover, diversified crop rotations in the case of annual crops or plant associations in case of perennial crops.
Carbon and energy	Technologies that increase soil carbon and save on energy requirements, by minimizing tillage or inputs. Residue management, legumes-catch cropping can also be classified in this category.
Zero Tillage (ZT)	Also known as zero-till, no till, direct seeding and direct drilling. Uses a tractor to seed wheat directly into unploughed fields with a single pass of the tractor.

Note. Information sources: (CIMMYT, 2015; Erenstein & Laxmi, 2008; FAO, 2015)

3 Results

This section describes farmers' characteristics and their cropping systems, then, presents findings to each research question. Finally, the FCM results close the section. Interview quotes are presented in Italics to facilitate reading.

3.1 Participants

In total 25 male farmers were interviewed with average age of 39 years old (age range 22-60), from two villages: Digmbra (16 farmers) and Kuboli (9 farmers). Households consisted of on average 7.8 members (range 4-12) with 1.5 members above 60 years old and 3 members below 18 years old. On average, farmers dedicated 66% of time to farm activities. In total 21 farmers reported to have other family members participating in farm activities 68-100 percent of their time, the average was 1.3 members per household. The 25 farmers reported on average 5 members per family who were either studying or doing household chores, they did not work on-farm nor off-farm. On-farm income ranged between <2000 to >10000 rupees/month (R/m), sixteen farmers earned between 2000-10000 (R/m). Table 3 shows most relevant information about income sources.

Table 3. Income sources for farmers.

Income	Number of farmers	Ranges (R/m)	Most prominent farmers Farmer Type
Off-farm	14	>10000	Part-time, resource-poor
Full-time farmers	5	2000 to >10000	Small vegetable
Pension	9	<2000 to 10000	Present in all types
Remittance	18	2000 to >10000	Part-time, resource-poor

3.1.1 Land size and ownership

For all farmers, average cultivated land size was 1.5 ha (range 0.38-9.2 ha) with 20% being rented. Four farmers had rented out land. Table 4 shows average farm size and land ownership according to farmer type. Land is a family property, in which the sons will inherit the land, while daughters will not inherit the land and will leave to their husband's house as soon as they are married. Farm size would increase due to farm expansion but decline again through inheritance. For example a well-endowed farmer, who owned 3.92 ha, explained: *"My grandfather had 32.5 acres which were divided among five sons, each inherited 6.5 acres. My father purchased 2.5 acres, so in total the farm has 9 acres. This will be split between my brother and I, 4.5 acres each. I only have one daughter now, I have no current plans for next generation."* Another small- vegetable farmer, who started landless but now owned 1,520 m^2, reported: "*My grandfather didn't have any land. My father was a worker, he* *owned 2 Katthas (256 m^2) in which my mother constructed a house. I have purchased 10 Katthas (1,264 m^2) in a period of 22 years. I will divide between three members, my two grandchildren (two sons died) and one son."*

Table 4. Farm size and land ownership per farmer type.

Farmer type	Average Cultivated land (ha)	Average Owned land (ha)	Owned percentage
Resource poor worker	0.42	0.34	80%
Mixed-livestock and crop	0.98	0.73	75%
Part-time	1.90	1.60	84%
Small-vegetable	1.74	1.32	76%
Well-endowed	5.29	4.30	81%

Note 1. Land size ranged from 0.38-9.2 Ha.

3.1.2 Cropping system description

In Bihar the predominant cropping system used to be mung bean-rice-wheat (Kharif-Rabi-Zaid) (Frelat et al., 2015). Nevertheless, according to the survey results, on average of their land fallow 30% Kharif, 0% in Rabi and 49% in Zaid, this means farmers are skipping mainly Zaid. The dominant crops per area were respectively: Wheat, Maize, Tobacco, and Potato. Farmers also reported growing other vegetables crops in the three seasons. Table 5 presents classification of crops per farmers' use. Mixed crops can serve as household food but also are regarded as "easy to sell" crops. Maize varieties are able to grow in Kharif and Rabi and can stay in the field until Zaid. Only 25 percent of farmers reported growing Sesbania with fuel use purpose. The most common cash crops were tobacco and mango, the orchards ranged from 5-40 years old. Seventeen farmers reported to have livestock, in average 2.5 per household, predominately cows. On average 70% of the milk was sold, that is equivalent to 2 Lt per household (HH) per day.

Table 5. Crop classification according to farmers use

Farmers use	Season			
	Kharif	Rabi	Zaid	Permanent
Months	October to March	March to June	June to end-September	All
Household crops	Rice	Wheat, potato, lentil, mustard	Mung bean	Yam (2 years)

Cash	Maize	Tobacco, maize	Maize	Mango, litchi, bananas, papaya
Mixed (Livestock, market, fuel and/or HH)	Cauliflower, faba, pointed gourd, sesbania, soybean, turmeric, sorghum, oats.	Faba, garlic, pea, sponge gourd	Pointed gourd, pumpkin, sesbania	

Table 6 shows average number of crops grown and the rounded percentage that goes to HH consumption, market or for fuel. Results show that there are diverse cropping systems, with more HH crops, followed by mixed and cash crops. Cover crop (*Sesbania spp.)* was only present on three farm types and its main use was fuel.

Table 6. Number of crop and destination according to farmer type.

Farmer Type/ Crop	HH		Mixed		Cash		Cover	
Use	M	% market	M	% market	M	% market	M	% fuel
Part-time	4	42	1.8	62	1	97	0.2	100
Well-endowed	5.2	53	1.8	76	2	54	0.6	100
Mixed LV and Crops	4.2	28	3.2	56	1.2	78		
Vegetable	2.4	39	2.6	55	1.2	69		
Resource-Poor	2.4	25	2	51	0.2	25	0.2	0

M= mean of number of crops grown per farmer, HH= Household. LV= livestock

Note 1.See Table 6 crop classification criteria.

3.2 RQ 1: Farmers future vision and effect of climate change.

To answer this research question, three items were included in the questionnaire: farmers' future view, motivations for farming and challenges. Content analysis classified farmers' answers into categories; they addressed two different expectations when asked about their future farms: Household Food Security (HHFS) and productivity or profit maximization. Twelve farmers talked about ensuring HHFS in the future by either keeping livestock and/or the current crops. For example, one mixed crop and livestock farmer said: "*I will continue farming only for household consumption; cereals and pulses are the most important for me. It is better quality when I grow my own food and it is cheaper than the market. My children will not farm. They will do other activities. So the balance between my off-farm job and the farm will be kept.*"

Another twelve farmers mentioned interest in growing or expanding cash crops that ensure profitability: mango (6 times mentioned), followed by vegetables (3 times) and tobacco (2 times), banana (1 times), also they mentioned to improve the livestock (3 times). For example, a small vegetable farmer who was growing tobacco in 50% of his fields with a farm size of 0.4 ha reported: *"I will keep the buffalos, the milking is basically for the family, if I see it is a good business I will increase the number. I could plant maize by improving irrigation machinery. I will increase tobacco because it has a good price. My farm will remain in the same size, it is enough for my family. A male will inherit the land."* Another situation was one part-time farmer who reflected upon his desires and his current farm: "*I will keep growing the same crops basically for my family's diet, I also want to have livestock but my children would have to help me. After finishing working outside, I will return to manage my farm. If I could find a job here, I would rather stay. And for the future, I would like to grow potato and vegetable crops*." When looking at these objectives by typology, there are three options: (1) Increasing productivity, (2) HH FS, (3) mixed of productivity and HH FS. Figure 6 shows objectives per farmer type.

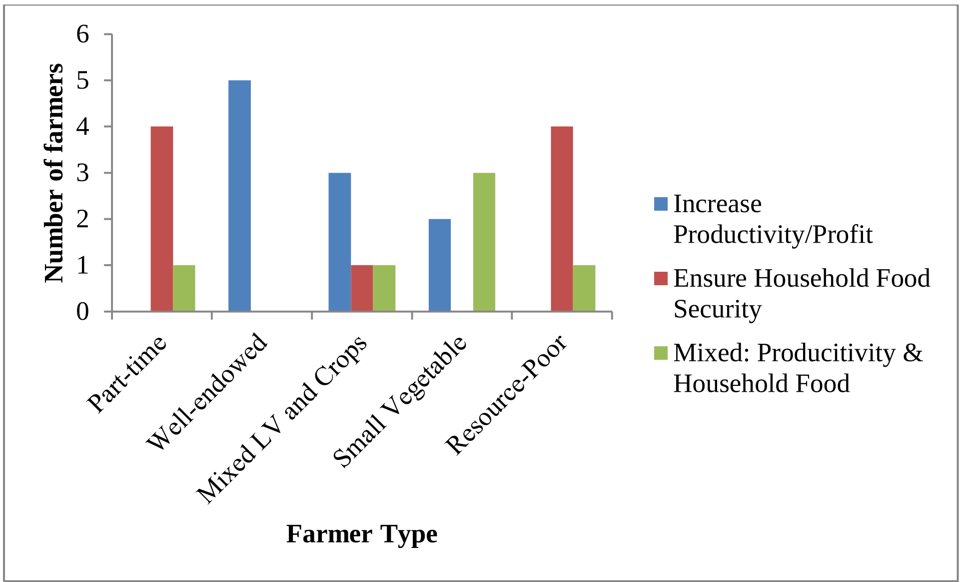

Figure 6. Objectives according to farmer type.

Throughout this future vision resource-poor type farmers mentioned that they would keep working outside to ensure enough income as farming is not a sufficient source. For example, the following quote of a resource poor farmer (0.29 ha) growing wheat, potato in Rabi, maize mung bean and sorghum in Zaid and continued with maize and sorghum in Kharif: *"Depending on the situation I will continue or change crops, I will still farm because both incomes are necessary, food is too expensive to purchase from the market, so I need to combine both. I will keep the same cow. If there is a female calve we will keep it for the family's milk."* Another example is from the a farmer that works in Nepal most of the time but still manages to come to Bihar for the critical farm periods: "*I will continue to work outside, I have four girls and the work in Nepal is stable. I am interested in other vegetable crops like: eggplant, ladyfinger, and chili. They are easy to sell and with a good price."* This view shows a mixed objective, because the crop use was for household and market purposes.

Furthermore, mango cultivation was seen by six farmers as an escape crop because as it requires less labor and management and it is profitable. An example is from a mixed crop and livestock farmer who already had 1 ha out of 2 ha as mango orchards: *"I will probably be shifting to orchards because there is more profit, management is easier and better climate adaptation."* One well-endowed farmer who had 0.8 ha of mango out of his 4 ha reported: "*I will increase the mango orchard in the future in uplands, it is a profitable business with less management requirement. In lower lands I will grow banana."* In addition, farmers did not describe specific farming plans, but their answers centered on facing situations as they came. For instance, a small vegetable farmer who was sick in the past said: *"I still do not think about the future farm, it depends on the situation. If I had the opportunity to leave farming I would. I would rent my farm and have a share basis. My brother is not active due to sickness. I have also been sick in the last 2-3 years so now my nephews are managing the farm. I am teaching them."* While four farmers considered the option of quitting agriculture if they had the chance.

Ten answers addressed technology adoption to improve irrigation and decrease labor requirements or improving their current practices (i.e. livestock management). For instance a resource poor farmer who owned 0.24 ha and grew rice in Kharif, wheat and potato in Rabi, fallow land in Zaid said: "*I will keep farming and working off-farm. I will switch to maize in Kharif because rice was a failure. I am thinking to purchase a water pump. The size of the farm will increase a bit but still keep the same family participation; we will hire labor if needed. Whenever I have irrigation, I will be able to grow rice, wheat, maize, mung bean. I already have some banana trees that I will start growing for the market."* Another example is from a young resource poor farmer who is part-time studying. His father works off-farm and comes for the critical periods. They have 0.40 ha in which they grow wheat in Rabi, maize in Kharif and Sesbania with fallow land in Zaid: "*I plan to introduce new technologies; my dad is working outside because there is not enough income from the farm, I will earn outside as well and then hire labor. I do not plan to have livestock because it requires too much labor and feed. My brother and I will earn outside."*

In the introduction a hypothetical model was introduced to explain how farmers incorporated CSA technologies in their farms, it was proposed that if they had positive experiences there would be a reinforcement of the technologies. This was confirmed when farmers were asked about the activity or part of the farm they were most proud of. Farmers' answers addressed three different topics: being successful when adopting a new technology (10 farmers), household food security (9 farmers) and good income especially from mango and tobacco growers (6 farmers). For example, one farmer that had adopted raised bed planting said: *"I am proud of the permanent bed planting, until now the crop is healthy."* Another farmer that had adopted Zero Tillage said: *"I was one of the first* [in the town] *to introduce zero tillage in my farm and I have pretty good wheat".* Another mentioned the mango orchard: *"it is less investment, high output, good to eat and a source of wood as well."* Another farmer explained how farming has given him a stable income: *"I was able to buy land, it's the first generation in my family and I have had a good income from agriculture."* About household food security, one farmer said: *"Being able to produce milk and food for my family. It also satisfies me to have my own farm and look up for it. When I harvest wheat, rice, potato, there is abundance."* As the quotes show having positive results when farming reinforces the activity and if there is a good experience with CSA technologies, then the farmer will engage and evaluate which other technologies can support him.

Another segment of the questionnaire inquired about their past, present and future challenges when farming. Figure 7 shows answers per most recurrent topic, climate is the most named present and future challenge. As explained in the methodology of the questionnaire, this question inquired separately from climate change. This is because assessment of the top challenges in farming aimed to confirm importance of climate. In addition, by reviewing past, present and future, respondents were explaining changes in them.

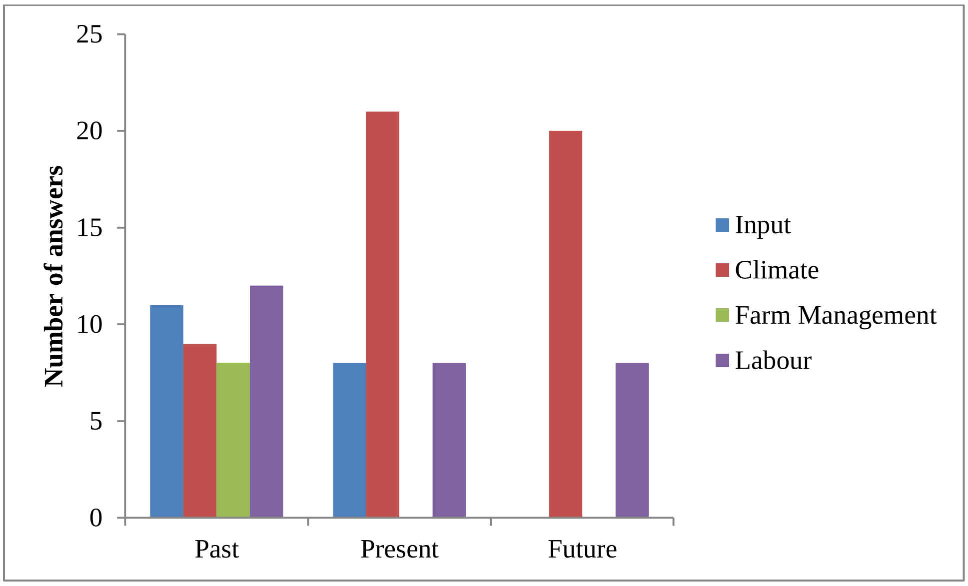

Figure 7. Top challenges in past, present and future according to farmers.

For example, as past challenges one farmer referred to: "*The cost of machinery was high and scarce. The varieties of wheat and rice were not as good as today."* Another farmer said*: "We didn't have a maize thresher* before; *pumping machines were not good quality."* About present challenges, farmers were mentioning scarcity of rainfall and the ground water being less accessible: "*The temperature is increasing in Zaid, so there is no soil moisture for mung bean. The water table is going down so its more difficult to get water and more expensive"*. Another farmer illustrated the ground-water problem*: "Water level is going down; two years ago I could pump enough water to irrigate 1.5 Katha per hour, now I can only irrigate 1 Katha in per hour. The level is going below 30 feet."* As future challenges, one quote summarizes it best: *"Water scarcity in rain and ground. Migration outside of Bihar and other better payed jobs, will make labor scarce. The next generation doesn't want to engage in farming."*

When asked specifically about climate change, some farmers commented about changes in the last 30 years, others explained the changes in the use of up and low lands. Through content analysis, Table 7 shows classified farmers' answers per topic within the seasons, other changes related to pest and diseases and other contextual changes.

Table 7. Farmers' perception about climate change[1].

Aspect/Season	Kharif (July-October)	Rabi (October-March)	Zaid (March-June)
Rain	Smaller amount, less frequent, un-timely. Drought last year.		Drought, not enough soil moisture for mung bean.
Temperature		Higher in October and November. Increasing faster in March. Difference between day and night temperatures is increasing.	Increasing in general. Higher in March, April.
Use of land and change in agricultural practices	30 years ago there was flooding in low lands, upland had rice. It has stopped due to changing raining patterns, now uplands are fallow lands or maize, and lowlands have maize, vegetables or fallow.	Lowlands used to be fallow in Rabi, now tobacco area has increased while wheat area has decreased. October and November were optimum for sowing wheat but now temperatures are higher after it is planted so there are yield losses.	About 15 years ago, low lands were cultivated with mung bean, and uplands were fallow. Now, there is less mung bean in the region.
Season Start date	Delayed (20 days).	Delayed	
Pest & Diseases	More disease in livestock, lower milk yield due to increase of temperature. Specifically, food and mouth disease in cattle. Mango started to have more pests and diseases (black tip of mango). More disease in Papaya.		
Other changes	More farmers in the region are switching to orchards, rapidly since 2010.		

Note 1. Summary of 25 farmers' comments.

In addition, farmers recalled three different types of important climatic events such as floods, droughts and fast winds (Table 8).

Table 8. Farmers recalled climatic events[1].

Climatic Event	Years	Consequences
Floods	2007, 1987, 1997	Rice losses. The entire region was completely inundated. One farmer recalled he lost 50% of mango yield in 2007. In 1997 there was hail.
Droughts	1990, 2003, 2015	Lower yield. In 2015, 20-25% loss. Zaid planting was interrupted because of lack of soil moisture. Maize started to be irrigated. Rice was less grown since five years ago, even in 2015 three farmers reported to abort this crop.
High speed winds	2015	Wheat maturity time was faster.

Note 1. Summary of 25 farmers' comments.

To summarize findings for RQ1, there are two farming objectives: productivity and HHFS, and some farmers combine objectives. Climate change was the main present and future challenge. Farmers' description related changes in use of upland and lowlands, increase in maize and decrease in rice cultivation, increasing temperature throughout the year. As can been seen in the quotes of farmers, their future farms would have could have more cash or escape crops, they would adopt agricultural technologies. Some farmers mentioned they would quit farming or initiate other economic activities, keep their off-farm and on-farm income balance.

3.3 RQ2: Farmers' long-term objectives and CSA Technologies as a support.

In this section, adopted technologies and their perceived benefits will be presented. Figure 8 presents the CSA technologies that have been adopted by the different type of farmers, the most used technologies are: Zero Tillage, Legume mulching, Raised Bed Planting, Irrigation Schedule for wheat and Improved seeds. Note that they been adopted by all farmer types.

Perceived benefits were grouped as follows: productivity includes changes in yields, income and input efficiency as it makes the farming operations more profitable for farmers. Resilience clusters benefits that relate to water use efficiency and reduce climate change risks in this area (Table 9). No perceived benefit matched the mitigation principle. In addition, Figure 9 shows the perceived contribution of CSA Technologies to productivity and resilience principles.

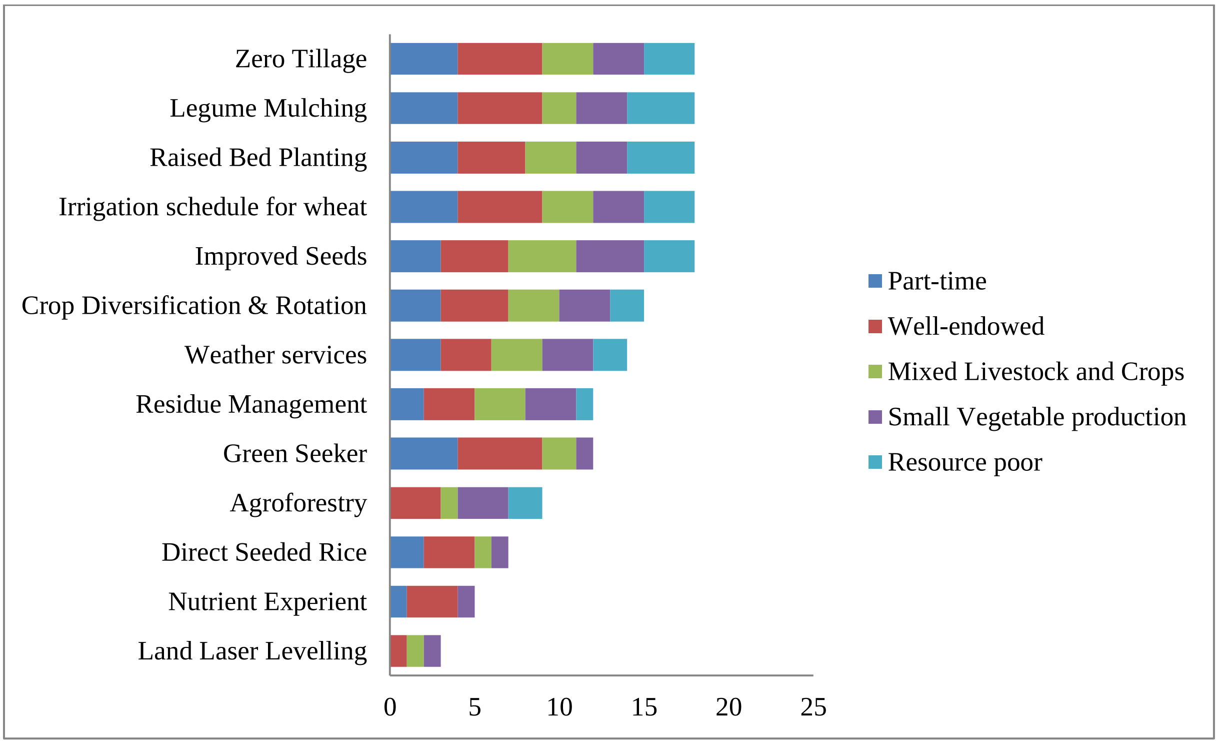

Figure 8. CSAT adoption by farmer type

Table 9. Benefits from CSA perspective

CSA Objectives	Benefits perceived by farmers	Total number of times benefits were perceived
Productivity	Increased yield, better food security, better income or more sources of income, less labor, better access to fertilizer, forestry products (wood, fruits), better livestock nutrition, better product quality, less costs, easier or safer income, less risk for loss for crop and livestock, better wellbeing, better crop development, easier crop management, input efficiency, less weed, optimal area use	209
Resilience	Better soil fertility and structure, less risk related to drought, less risk related to flooding, better access to water, disease/pest prevention, insurance for other crop losses, production diversification, reduced crop time, better drainage, better soil moisture	61

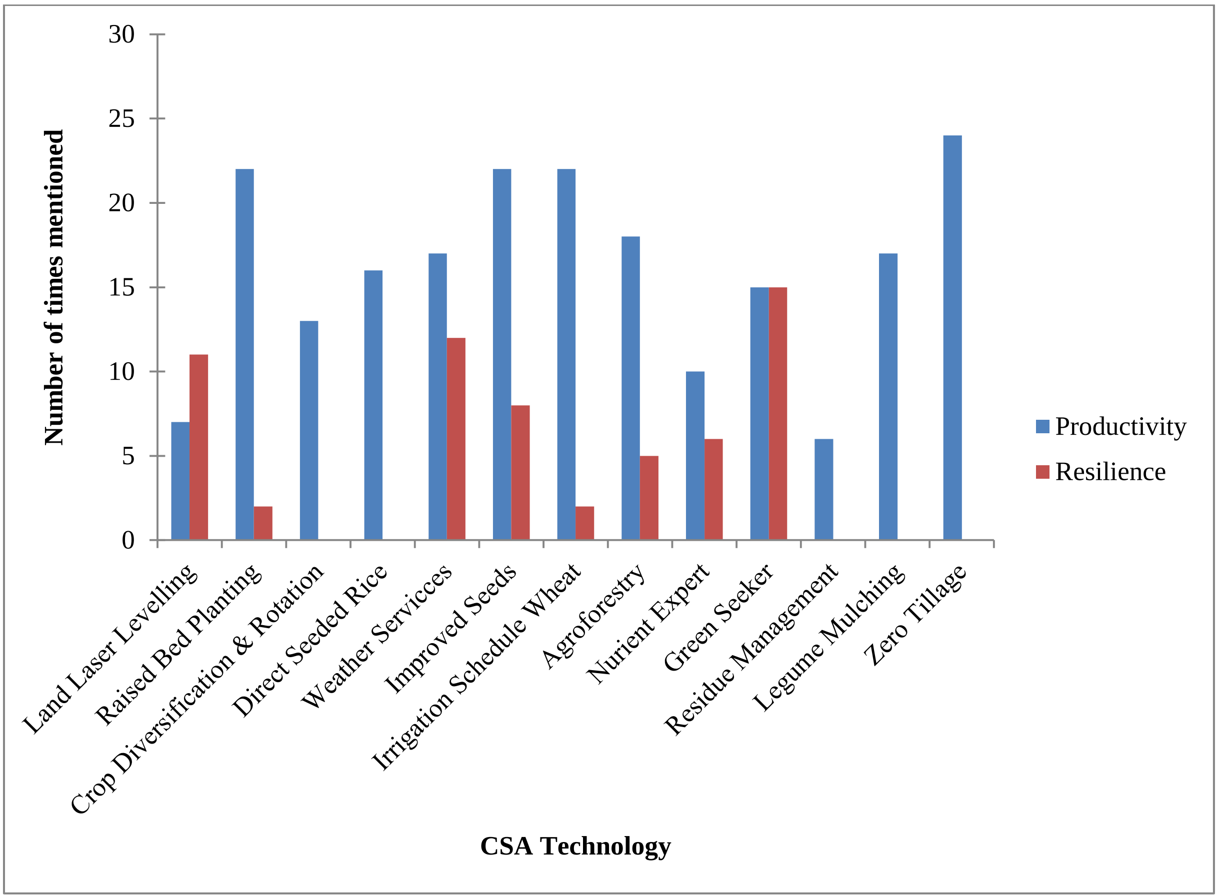

Figure 9. Productivity and Resilience perception per CSAT.

Farmers rated Zero Tillage, Raised Bed Planting and Green Seeker among the top-3 technologies for CSA (Figure 10).

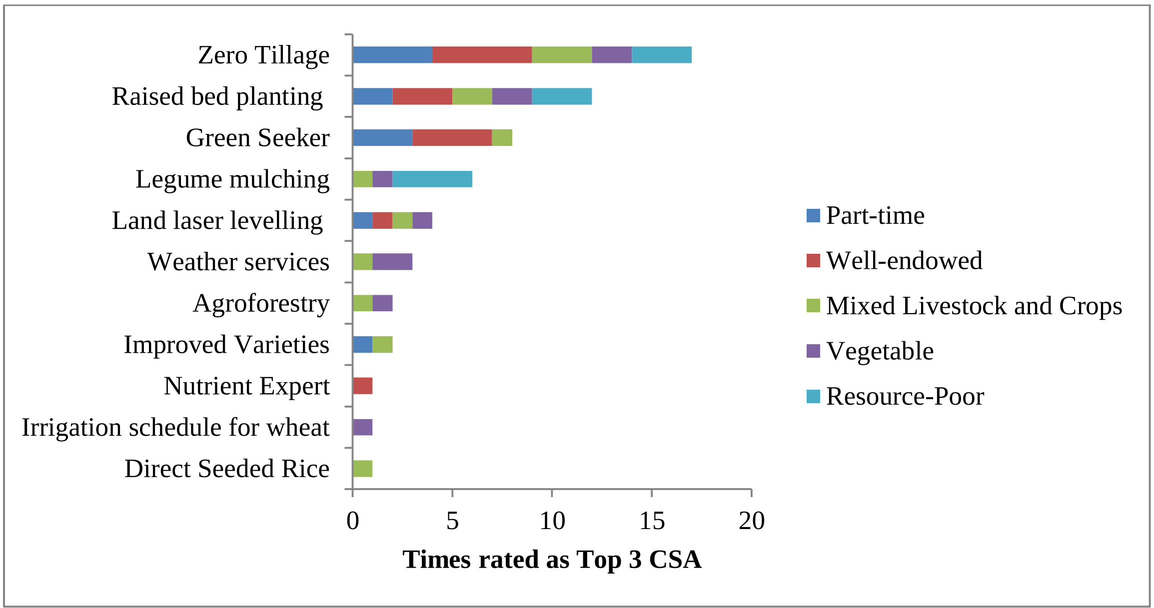

Figure 10. Farmers' rating of most impacting CSAT's.

3.4 RQ3: Transformation of objectives and constraints into Farm DESIGN (FD).

Based on understanding the farmers' context, their objectives and constraints they were summarized to be able to input them in FD model (Table 10). Since the majority of farmers focused on productivity and perceived benefits that aim at productivity, maximizing profit was identified as an objective for all farmers' types. As discussed before, optimizing HHFS was one of the main objectives when farming, this was selected for all farmers except well-endowed ones. The reason to do this, was that the FD allows to compare optimization in two objectives simultaneously. Therefore, for well-endowed farmers, labor balance was prioritized since they hire most workers when compared to other farm types. Water requirement was set as constraint due to the recurrent comments on the irrigation challenges that they are facing.

Table 10. Objectives and constraints for FD.

Farmer Type	Productivity	HH Food Security	Labor source	Water constraint
Resource-Poor	Yes	Yes		Yes
Mixed livestock and crops	Yes	Yes		Yes
Part-time	Yes	Yes		Yes
Small Vegetable	Yes	Yes		Yes
Well-endowed	Yes		Yes	Yes

Other valuable information considered as useful for the inputs of FD was for instance:

- When choosing possible cash crops, farmers argued profitability and market output. Therefore, this facilitated creating new farm scenarios with local successful crops such as mango, tobacco, vegetables, papaya and banana.
- Increasing the rented land near 20 percent of the total farm can be set up as a possibility to optimize farming systems as this was currently the situation in the majority of farmers. Indicating that land is accessible and available in the nearby areas and solutions that suggest increasing farm size are feasible through rented land.
- Sesbania used as fuel mainly, this influences Soil Organic Matter levels added by the crop residue.
- Elimination of options for increasing Soil Organic Matter through leaving cereal crop residue. Straw is for feed or sold but barely left on field because as neighbors come and take it. Some farmers reported can plough it in the fields occasionally.

3.5 RQ4: Role of CIMMYT and BISA from farmers' perspective: adoption of CSAT.

Farmer's suggestions regarding the support of BISA and CIMMYT addressed different topics (Table 11). Famers named four information sources when adopting a CSAT (Figure 11). Seeing the BISA trials convinced farmers for adopting a technology in all farmers' types. For poor-resource farmers, neighbor's information served as channel to learn and follow adoption of CSAT. In small vegetable farmers, their experience with the CSAT was a major argument to adopt and keep it. None of the mixed livestock and crop farmers referred to the BISA technicians as a source for adopting CSAT.

Table 11. Farmers' suggestions on topics for BISA and CIMMYT.

Topics	Farmers interest
Soil	Soil health diagnosis and testing
Water	Irrigation (drip, boreholes, deep wells)
Crops	Tobacco seeds. New improved varieties for wheat, rice and vegetables.
Knowledge	Regular advisory. Vegetable production. Mango orchard Management. Wheat advisory.
Processing	Combine harvester for wheat, rice and maize, can be on rent basis. Processing facilities to export mango.
Machinery & Technology	Availability of small size Land Laser Levelling. Availability of Green Seeker and Zero tillage machinery. Nutrient Expert access (this application requires a smart phone or laptop).
Livestock	Fishery and poultry. Dairy business. Livestock nutrition management.
Institutions	Link with financial organizations for developing new projects.

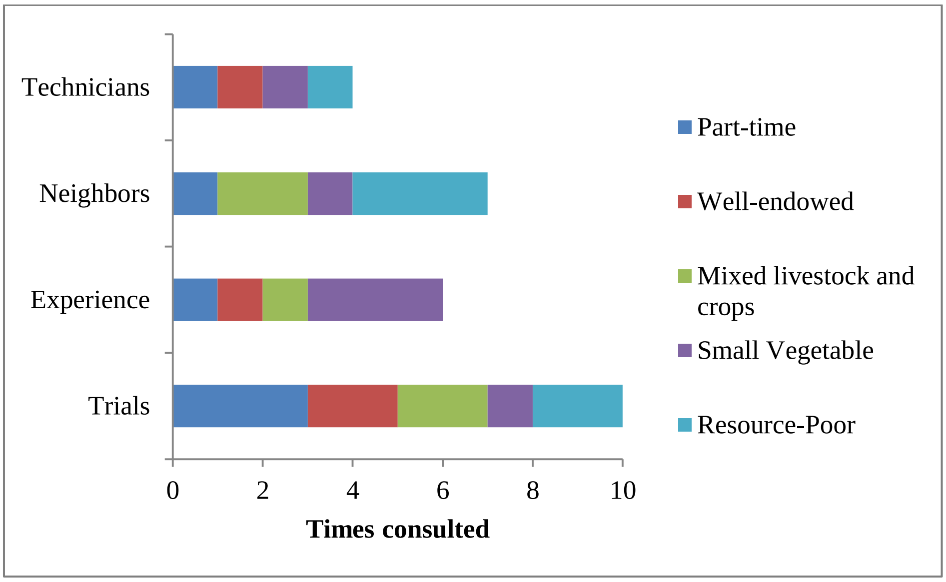

Figure 11. Consulted sources in CSA technology adoption.

3.6 RQ5: Constraints of CSAT's.

In this section, addressed constraints by farmers will be presented and as well the feedback session results as it complements constraint understanding. It should be clarified that in parallel, the FCM was made with CIMMYT experts which also analyzed farmers constraints, which will be discussed in the next section.

Farmers were directly asked about the constraints they had experienced with CSAT. These were grouped in topics: performance-related, limited-resources, limited-knowledge and skills, others. By performance constraints, farmers commented problems they had when using the technology. Resource-limited addressed water, land, machinery availability, competition for fuel or livestock feed. By knowledge and skills, farmers addressed problems related to operate new machinery or not knowing details of new practices. Others constraints are some comments regarding culture, wild animals, that is not directly related to the CSAT. Table 12 describes constraints per technology and includes which farmer types addressed them. Figure 12 illustrates the most frequent constraints by CSAT, which are perfomance-related and resource-limited. This combination of constraints results in the low or partial adoption of CSAT.

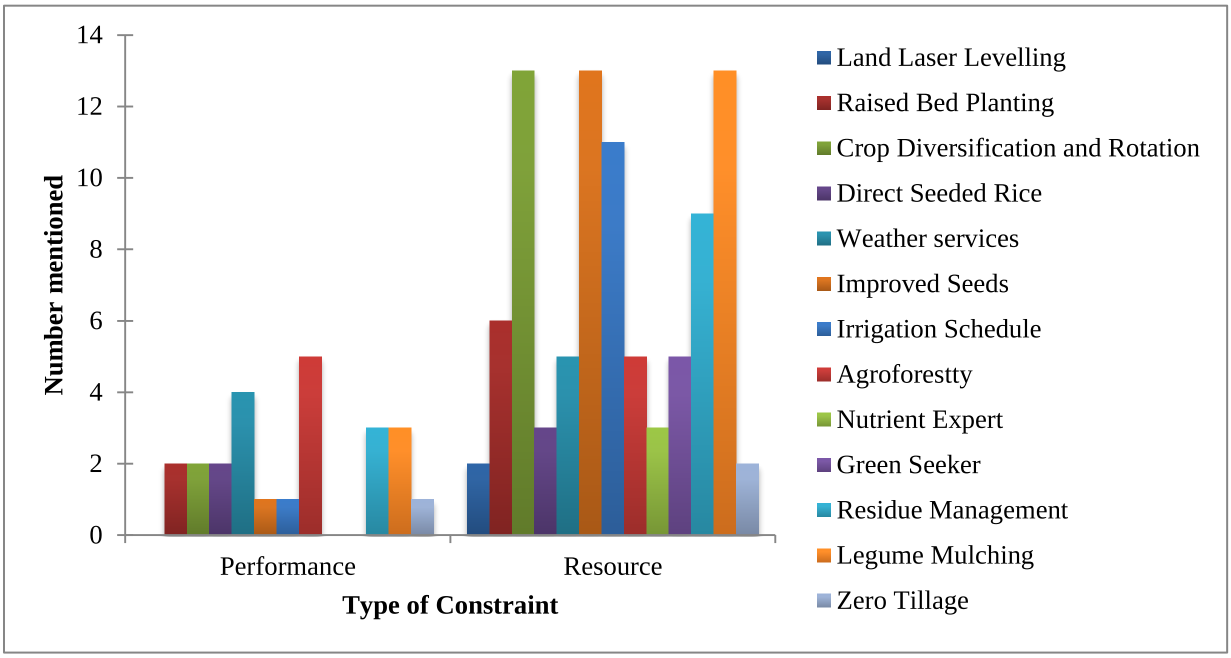

Figure 12. CSAT classified by performance and resource constraints

Table 12. Constraints per CSAT and farmer type.

CSA Technology	Performance-Related	Farmer Type	Resource-Limited	Farmer Type	Lack of knowledge & skills	Farmer Type	Other	Farmer Type
Land Laser Leveling			Not available or known	1,3,4,5	Requires knowledge on machinery operation	2		
Nutrient Expert Software	Does not consider all the price fluctuations input have	2	No internet or electricity access or not available or known.	All				
Direct Seeded Rice			Not growing rice anymore.	1,3,4,5			No difficulty observed.	2
Green Seeker			Not available	1,3,4,5				
Weather services	Low accuracy	All			Would prefer audio messages on cellphone.	1,3,4,5		
Raised Bed Planting			Crop rotation is limited, only used to maize. Some farmers did not know there was a seeder accessory for the permanent beds.	2,5 1,2,3,4	Too much depth in seeding so low emergence rate.			
Agroforestry	Shade in trees, too much weed	1,2,3,4	Not available or known	1				
Irrigation Schedule for wheat			Poor irrigation technology, watering with hose disturbs the tillers. This affects wheat specially. Or High water costs	All				
Residue Management	More pest and diseases	3	Competition for livestock feed or fuel with straw	All				

Legume Mulching			Not enough time between seasons. Competition for fuel (sesbania), mung, faba bean (feed). Mung bean establishment depends on soil moisture. No seeds availability for sesbania. Higher costs (planting but also mulching).	All				
Crop Diversification & Rotation			Difference in upland and lowlands limits the suitable crops, too few plots to rotate, and too small area to diversify.	3,4,5	Requires knowledge to have a crop rotation	2		
Improved Seeds	Quality control not guaranteed when buying	All	Not always available at BISA.	All				
Zero Tillage			Machinery not always available in town.	1,3,4,5	Too much depth in seeding so low emergence rate.	2	Older generation prefers bare fields.	All
Not directly related to CSA							Presence of wild animals	2

3.6.1 Feedback session with farmers

The feedback session supported the validation of most relevant objectives and constraints and their possible alternatives. So far, a major challenge of FD model is to bring it back to farmers, currently the model is used to design alternatives for farming systems in the academic context. There is an opportunity to share knowledge and explore feasibility of the cropping alternatives with farmers. Based on this, the session structured to share the FD model in a simple form to create awareness (See Annex 3-Details of feedback session with farmers.). Then, according to the questionnaire results on CSA technologies and with observations when visiting farmers, three topics were chosen for improvement: (1) better manure management, (2) increasing N-fixing legumes, (3) reducing crop water requirement. In addition, there was a discussion about constraints in technology adoption such as land heritage, social pressure and machinery availability. Table 13 summarizes farmers' feedback. Shortly, future FD alternatives can include scenarios in which legumes increase for N-fixation, manure management is improved and cropping selection considers crop water requirements. About current constraints with CSAT, ZT and Raised Bed Planting have been adopted partially due to machinery availability and other residues use.

Table 13. Farmers' comments per topic of feedback session.

Topic	Farmers Feedback
FD Nutrient Cycle	They liked the explanation when nutrients exchange was a simile to money exchange, they could see how N and C left their systems. It was the first time that farmers saw their farms in a cycle. Although they had thought about it, they had not pictured it.
Manure management	Eleven farmers had open heaps, 2 were already producing vermi-compost. They saw it feasible to cover the heaps with palm leafs. About the straw addition, it was seen as competing resource (sold or taken by neighbors) so that was hard to integrate in the manure.
N-fixing crops	Understood the benefits and would evaluate planting different legumes, some farmers shared experiments that they were doing. They also said that past generations had more legumes in their farms.
Water saving crops	For some crops farmers thought they required more water, although local information was used (Official Agricultural Guide in Bihar). They asked BISA if they could get support or networking for irrigation technologies.
Land heritage	One farmer suggested that they could talk to two generations above to start considering working as families.

First group farmers	Farmers needed information on mango management, they already intercrop but stop after 5 years due to big canopy, they would need knowledge. Information of other productive varieties of mango is scarce. Hard to find support in government agencies and with local leaders.
Second group farmers	Seven farmers were using RBP, only 1 sowed with machine, the rest by hand. Zero tillage adoption was still partial, 5 ploughed and used line-sowing machine, and only 1 did not ploughed. Moreover, leaving residue in the field was not feasible for farmers. Networking for improving community machinery remained as a challenge.

3.7 Analysis of perceptions with Fuzzy Cognitive Maps (FCM)

Through FCM, CIMMYT experts illustrated their perception of constraints and benefits of CSA technologies and they proposed different alternatives. This section shows four expert maps and a final one that combines farmers and experts' views. With colors, in yellow are the CSA technologies, in blue the benefits, in red the constraints, in purple alternatives proposed. Thickness of arrows shows the weigh given by experts, positive signs are excitatory and negative are inhibitory relationships. At the end FCM metrics are presented in Table 15.

The first CIMMYT experts are working with CSA technologies for 2 years now in Bihar and Haryana (Figure 13). They indicated that crop intensification with Conservation Agriculture leads to soil improvement, better use of resources, smaller environmental footprints, improving nutrition security and higher productivity of crops. These highly productive crops minimize climate risks and require improved crop management. Constrains of Conservation Agriculture are labor availability, knowledge gap, lack of policies, market uncertainty, timely availability of the machines. An alternative to solve the machinery availability is to create service provider windows.

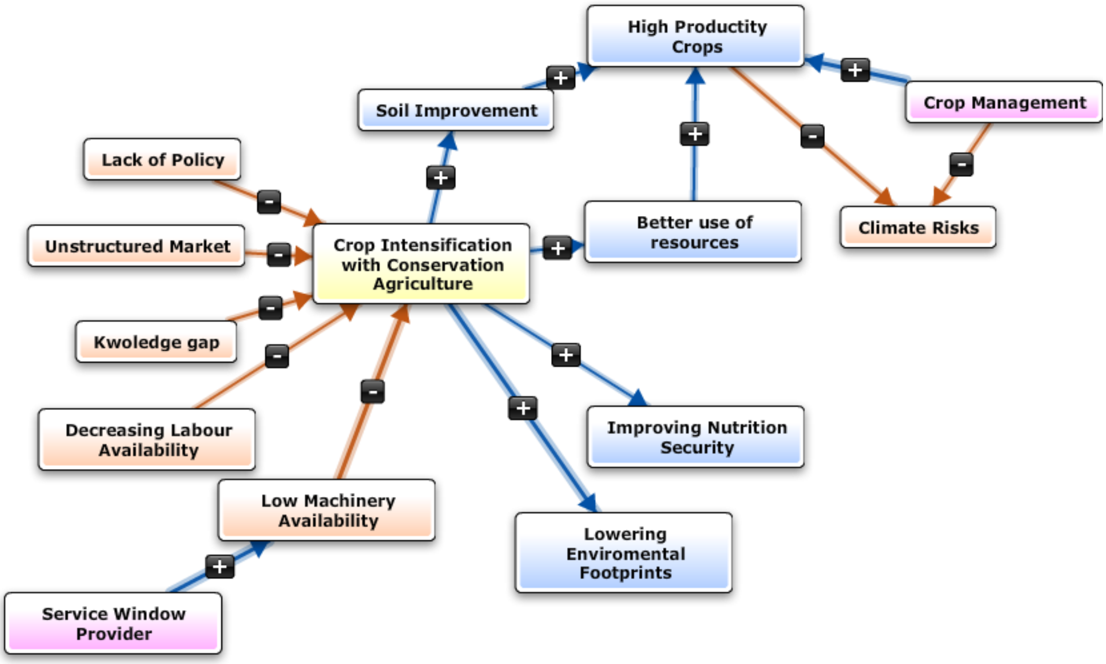

Figure 13. First FCM analyzing general benefits and constraints by CIMMYT scientists.

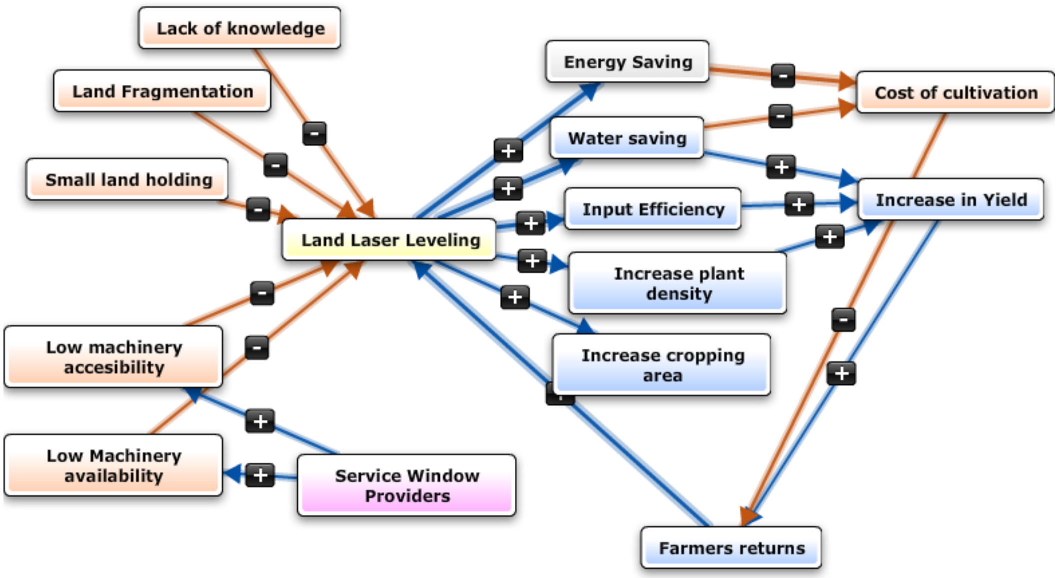

Figure 14. Second FCM Analyzing benefits and constraints of Land Laser Leveling CSAT by CIMMYT scientists

Same experts analyzing Land laser leveling (LLL) CSAT drew the second map, which is presented in Figure 14. LLL allows increased plant density, saves energy when ploughing, saves water (easier irrigation and better drainage), and results in higher input efficiency and an increased cropping area. All these factors will lead to higher yield, less costs of cultivation, which gives higher net returns to farmers. This LLL technology has constraints such as: land fragmentation, and smallholder farms which difficult entrance of machinery. Other limitations are: machinery availability, high initial costs and lack of knowledge. An alternative for these limitations is to create service window suppliers in the area to offer the LLL directly.

ICAR researchers who were also present during the FCM session drew the third map. It analyzed Crop Establishment Methods; it included CSAT like Direct Seeded Rice (DSR), Zero Tillage (ZT) and Bed Planting (RBP) as seen in Figure 15. By using these CSAT, there will be yield increase, decreased climate risks, higher economic returns, and lower costs of cultivation. This will increase the wealth of farmers, who will in turn have higher risk capacity, get grants for land to increase their cultivation area. There are two constraints: machine availability and land holding size caused by fragmented lands and low holding sizes.

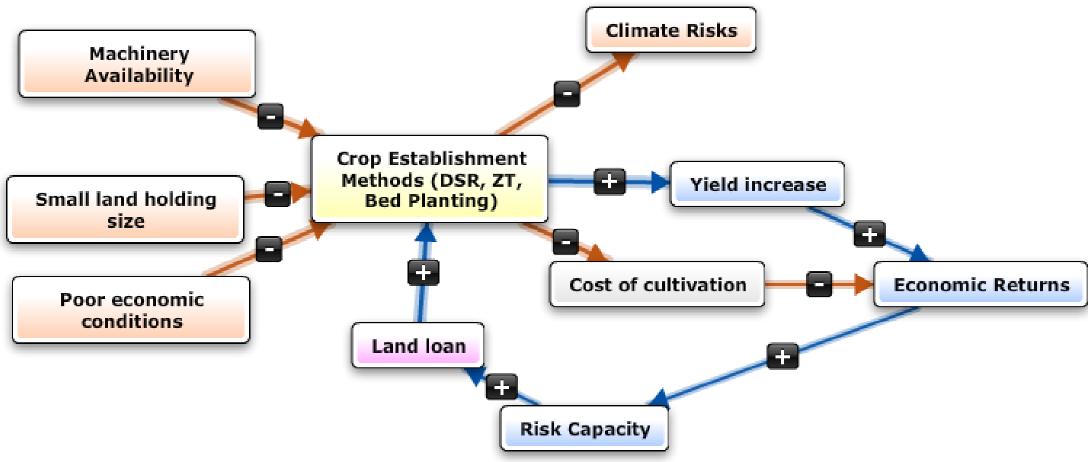

Figure 15.Third FCM Analyzing benefits and constraints of crops establishment methods CSAT by ICAR scientists.
CSAT addressed Direct Seeded Rice (DSR), Zero Tillage (ZT), Raise Bed Planting (RBP).

CIMMYT-Asia Director drew the fourth map analyzing CSAT (named Crop System Optimization and Conservation Agriculture), he was requested to consider policy level, considering that the other experts had field experience, it is presented in Figure 16. As seen, with the CSAT there is higher crop yield per unit area and input use, there is also time optimization in crop management. Nevertheless, the adoption depends on: market uncertainty, timely availability of inputs, high cost input, availability of machinery. To deal with market uncertainty the proposed alternative is to regulate the markets at block level (district subdivision), this can be done by assuring crop quantities that will be purchased and have a minimum support price. Regarding timely availability of inputs, the alternative is to assess the input demand in advance, there has to be quality check legislation and to strengthen the Private Public Partnerships (PPP) in the supply chain. Regarding the high cost of inputs, there should be an investment on efficient and low cost cultivation technologies and also a subsidy scheme. When analyzing the availability of machinery, options such as service windows, community shared machinery banks are proposed.

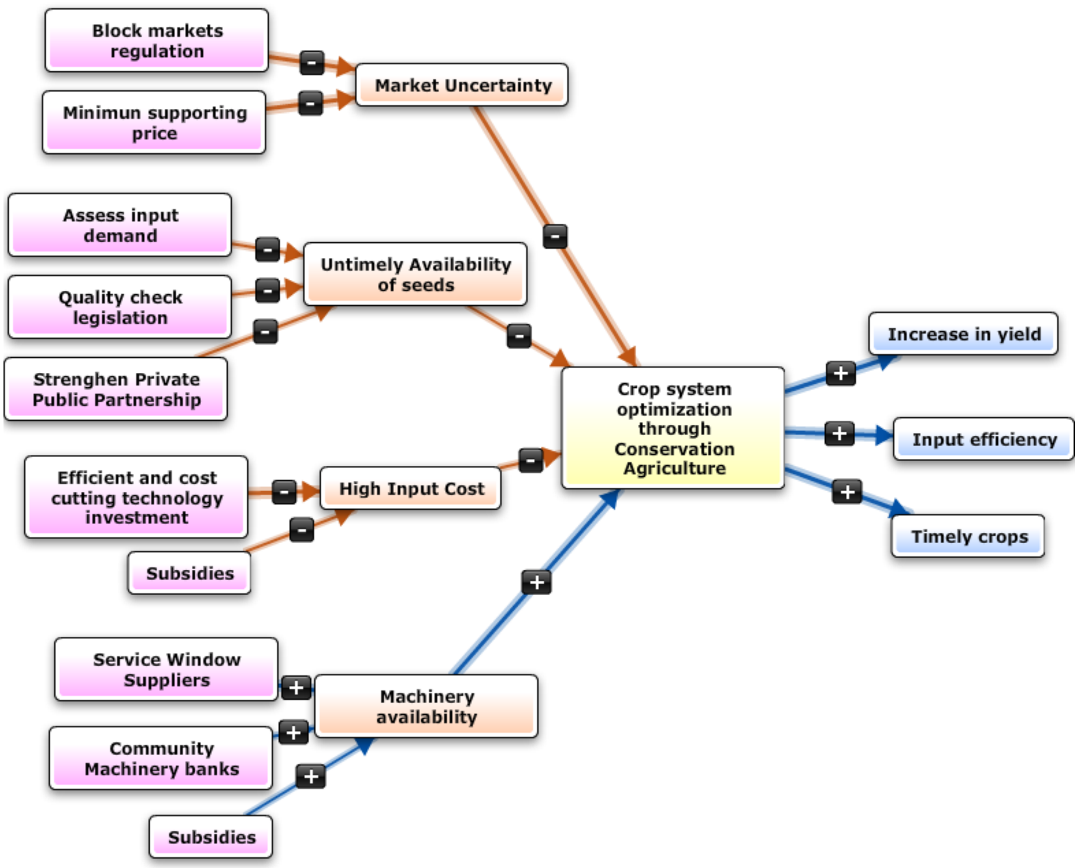

Figure 16. Fourth FCM analyzing policy challenges of CSAT drawn by CIMMYT-Asia Director

To synthetize, the first four maps showed CIMMYT experts view, who identified constraints related to resource-limitations (land size, investment, machinery availability and accessibility, uncertain and unstructured market) and lack of knowledge of the CSAT. The perceived benefits were classified into the CSA principles: decreasing mitigation (by lowering emissions), increasing productivity (by improving nutrition security, improving soil, increasing yields, decreasing inputs (water, energy), lowering costs of cultivation). Resilience (by having timely crops, decreasing water). These maps are an initial approach to understand constraints that farmers face, they are relatively simple with low density index. Which explained by having single relationships between the concepts (See metrics in Table 15). The coping alternatives proposed to face the CSA constraints, include: service window providers, improving crop management practices, improving investment capacity through land loans. The CIMMYT director map proposed alternatives that could be discussed at a policy level.

3.7.1 Final FCM

A final map synthetizes farmers' inputs and CIMMYT experts' views analyzing CSA adoption, as seen in Figure 17. The benefits are: increased soil fertility, input efficiency, water efficiency, food security and higher yields. Constraints are: resource limitations which are related to labor scarcity, machine availability, small land size, low knowledge and skills, high irrigation costs. Driving forces are: coping alternatives, good CSA experiences, climate change, market price and farmers objectives. Crop selection is a transmitting concept, it responds to high irrigation costs, market price, farmers' objectives and climate change, ultimately negatively influencing adoption of CSA technologies. Table 14 describes each FCM element. When compared to the experts maps, this final map has more relationship between concepts and the most concepts, resulting in low density and low complexity (See metrics in Table 15). It nevertheless, includes CSA experiences, increasing market price and climate change and farmers objectives as driving forces, integrating farmers view.

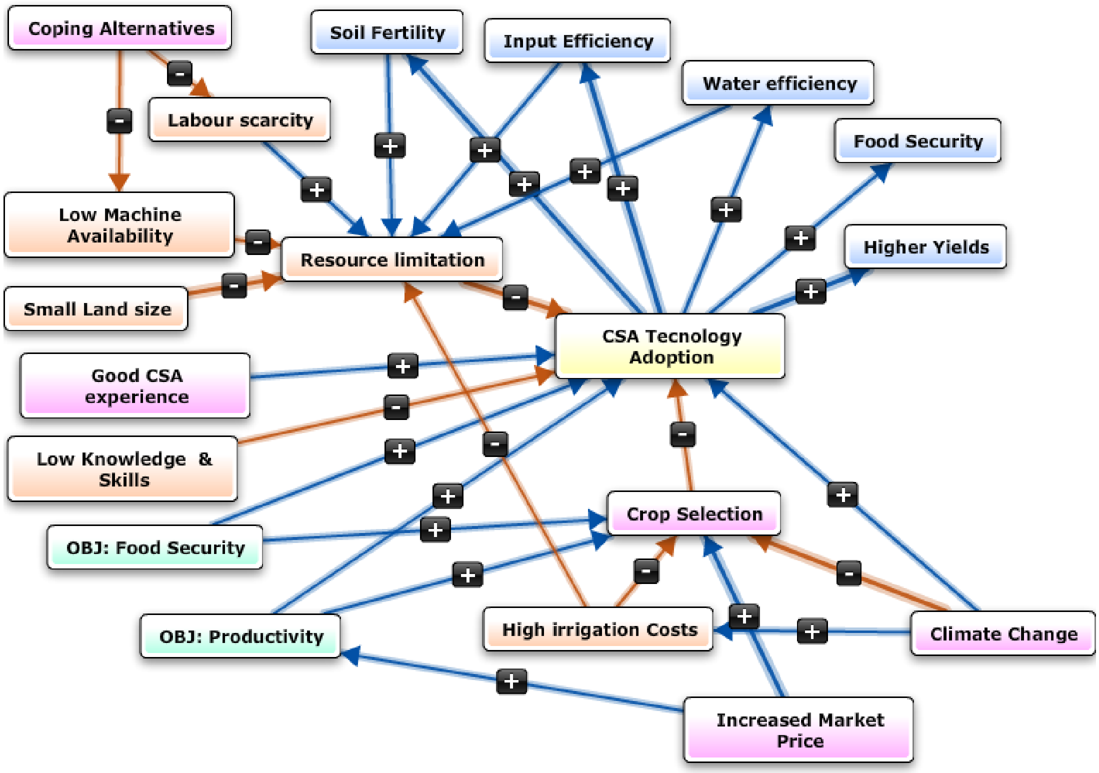

Figure 17. Fifth Final FCM including expert and farmers beliefs.

Table 14. Fifth FCM element description

Name	Description
CSA Tech adoption	CSA Technology adoption at the farm level.
Low Knowledge & Skills	Required to integrate technologies., e.g.: machinery management, crop rotation.
Resource limitation	Related to limitations in use of land (up vs. low lands), increased water cost and demand, availability of technologies.
Good CSA Performance	CSA performance in achieving productivity and resilience
OBJ Food Security	Farmers that grow crops for Food Security: wheat, rice, potato, lentils, mung, mustard.
OBJ productivity-profit	Farmers grow crops as a important source of income.
Climate change	Too low rainfall and changes in temperature affecting: zaid, kharif and rabi crops
Inc. Market price	Increased market price, specially cash crops and mixed crops. HH crops: wheat, potato would be sensitive as well.
Coping Alternatives	Such as: service window suppliers, crop management practices, subsides, market intervention, input quality legislation, Public private partnerships, Machinery banks.
High irrigation costs	Increasing cost due to lower ground water table and changes in rain patterns.

Crop selection	Crop sequence and diversity depends on objectives, irrigation costs, climate change, price. It relates to HH, mixed or market use.
Soil fertility Input efficiency Water efficiency Food Security Higher Yields	Benefits proposed by CIMMYT experts but also named by farmers directly.

Table 15. FCM Metrics

Metrics	First CIMMYT experts map	Second CIMMYT experts Map	Third ICAR experts map	CIMMYT director experts map	Final Integrating FCM 5
Number of concepts	14	15	10	18	19
Number of connections	15	20	11	17	28
Density	0.08	0.09	0.12	0.05	0.08
Connections per concept	1.07	1.3	1.1	0.94	1.47
Number of drivers	6	4	3	10	7
Numer of receivers	3	1	1	3	2
Number of ordinary	5	10	6	5	10
Complexity score	0.5	0.25	0.33	0.3	0.28

4 Discussion

So far, previous research on CSA programs has mainly centered on case studies across the globe, surprisingly there are no agreed indicators to measure effectiveness. As exposed in the introduction, technology adoption is a widely studied topic that has given insights into different type of constraints. This study aimed to analyze the smallholder farmer and researchers perceptions of importance, effectiveness and adoptability of CSA and associated technologies and practices. Secondly, it aimed to assess the farmer context to design suitable farm scenarios with another MSc. Thesis. It focused on the farmers, who are ultimately the end-user. This task required creativity but also competence in utilizing FCM and qualitative methods to obtain insights into where adoption limitations reside. This section starts with a summary of the findings, then presents a final review per topic and will reflect on contributions to the knowledge area, possible implications, limitations and future research suggestions.

Results show that farmers aim at ensuring HHFS and productivity. Regarding CSA adoption, farmers perceive benefits on productivity and resilience. They also face constraints such as limited resources (land, capital, facilities, irrigation, machinery), performance- related (lack of seed control, low accuracy in weather services) and low knowledge and skills (operating machinery, crop rotation suitability). Climate change is seen as a present and future challenge. Farmers' described changes in use of upland and lowlands, increase in maize and decrease in rice cultivation, increasing temperature throughout the year. They reported that 49 and 39 percent of farmers land were fallow in Zaid and Kharif due to low moisture in soils and changing raining patterns. In their future views, farmers considered to have more cash or escape crops, adopt agricultural technologies or practices. Some farmers mentioned they would quit farming or initiate other economic activities and keep their off-farm/on-farm income balance. When asked about support from CIMMYT and BISA farmers proposed topics that are beyond the CSAT offered by these institutes. On the other hand, in the FCM created by CIMMYT staff, main constraints related to machinery availability, capital investment, small-land holding sizes, knowledge gaps, high input cost and seed availability. While benefits addressed to productivity, resilience and mitigation.

4.1.1 Climate change and technology adoption

Farmers' answers showed how climate change is triggering adoption of CSA technologies. This was present in their current and future challenges. Farmer perception of climate change (see Table 7) was in accordance with scientific reports from Bihar in (Chhabra & Haris, 2015). Other authors in India have found similar results using interviews or discussion groups (Banerjee, 2014; Dhanya & Ramachandran, 2015).

The author's model of CSA Technology adoption (Figure 2) suggested that having a positive experience with CSA technologies reinforces adoption, but limitations (e.g. machinery availability or crop residue competition) can result in a partial adoption or rejection of CSA technologies. This model was consistent with farmers' experiences. It nevertheless leads to a sensitive question: when there is partial technology adoption, what is the real impact? Usually, research will present trials with a complete adoption, but as seen in Bihar, the majority of the farmers did not do Zero Tillage precisely but it resulted in a use of synchronized seeder and fertilizer machinery and ploughed fields with soils that did not have crop residues. These findings are similar with other research on Conservation Agriculture (Giller et al., 2002, 2009). Therefore, farmers may be facing similar challenges worldwide and adoption can remain partial, thereby decreasing the benefits of such technologies. Thus, addressing impact on productivity, resilience and mitigation is highly relevant in future research studies.

4.1.2 CSAT Adoption Constraints

This study argued that CSAT adoption combines different types of constraints. As an example, this was confirmed with the weather forecast. For instance, farmers in this study argued that there was low accuracy in the forecast and they suggested that it should come in a voice mail. Interestingly, another research found that dissemination of weather information is lower when farmers are smaller or don't have strong links to markets (Mertz et al., 2009). This shows interaction between farmers characteristics, quality of the technology and contextual constraints. Therefore, adoption is not a unilineal process in which technology can just be delivered to farmers. Into what extent should organizations like CIMMYT cope with farmers' resource constraints? Or how could CIMMYT develop a learning program to improve the knowledge and skills barriers? By taking the perspective of an end-user the limitations become clearer, there is a need for interinstitutional support, otherwise the technology may not be appropriate for the local farmer's needs.

How should a research institute design technologies that consider not only technical feasibility but also resource constraints (e.g. land holding size, labor, and investment capacity) or social aspects (e.g. market links, farmer priorities)? Where should the line of technology design and appropriation should be drawn? The concept of selective factors (Leeuwis & Ban, 2004) and exogenous characteristics are useful (Sumberg, 2005) in this regard. From the farmers views, other crops, livestock and water technologies were highly relevant for them. In contrast, CIMMYT director supported interventions in market and subsidy schemes. Connecting these views was partly done with the last FCM, in which CSAT addressed the multiple themes mentioned by the two stakeholders.

A short reflection should follow on using a typology approach. Considering that 80 percent farmers in Bihar operates land sizes of 1-2 ha in Bihar, it was highly suitable to consider the very smallholder farmers. As shown in the CSAT adoption (Figure 8) most well-endowed farmers have adopted a wide range of technologies. In the interviews it was assessed that resource-poor workers, part-time and small crop farmers were the least familiarized ones with the CSAT. This is an opportunity to rectify who is the desired user for CIMMYT technologies and whether land consolidation or community machinery banks are really suitable coping strategies to optimize CSAT adoption and ultimately the farming systems in Samastipur.

4.1.3 Methodological lessons

The first question arose when the selected participants for the interviews included only farmers that were familiarized with CIMMYT's program: what is happening with technology adoption or climate change perception in farmers that do not have the link to the organization? It would have been interesting to consider farmers without CSA technologies and to model their farms in FD to compare the impact and as well as their perception. On the other hand, there was a learning process about the culture, cropping systems and translation dynamics and when combined with the questionnaire application the data collection was challenging at the beginning. Nevertheless, this questionnaire facilitated the answer classification per topic to identify critical issues. Finally, the suitability of FCM for assessing constraints and objectives is questionable. It is rather a more interesting methodology to approach different stakeholders and generate discussions, but this requires a system thinking approach, a building up process of creating the maps and finally setting a discussion to understand differences between stakeholders, other studies had pointed out these limitations (S. A. Gray et al., 2014; Özesmi & Özesmi, 2004).

5 Conclusions

This case study evidenced the complexity of technology adoption, it found interesting examples of how different constraints limit CSAT appropriation. Farmers are facing challenges in regards to climate change. Although cropping systems may change in order to adapt to new challenges, this study confirms that household food security remained as a priority and technologies should ensure succeeding in it.

Related to the suitability of CSA technologies, in the case of Bihar, farmers constantly referred to the water constraints but there were no irrigation technologies promoted. This is due to CIMMYT technology portfolio. However, by not addressing water improvement directly, farmers are skipping cultivation in Kharif and Zaid cropping seasons. So even if there are adapted varieties of maize or rice, farmers do not have capital or water accessibility to grow them, therefore the technology may not be used. This calls for an inter-institutional cooperation in the region of Samastipur. Different research institutes and government offices can create a plan for agricultural development that articulate and address farmer’s needs. Other studies in Bihar suggested a similar pathway: subsidy and crop insurance schemes, strengthen institutional capacity to disseminate knowledge, regulate markets, among others (Taneja et al., 2014).

Future research needs in the area needs to urgently interview female farmers, as there is an opportunity to compare into what extent gender issues influence the access to CSA technologies and what improvements can take place. Strikingly, in the part-time type farmers, women were the ones operating the farm, so there are exceptional opportunities to approach this situation with a gender perspective research. In addition, there is an opportunity to continue developing dynamics that can bring farmers and modeling closer. In this study, farmers found interesting the overview of their farms in a nutrient cycle, games or group dynamics could further explore farming scenarios. This would require considering farmers as an end user and not as a source of information.

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Annex 1- Questionnaire for farmers

Climate Smart Farmers Detail Household Survey, Samastipur from 2015-2016

This is a CIMMYT Research Program that aims to support resource-poor farm families in tropical Africa, Asia and Americas to boost their income by integrating agricultural systems and intensifiing them, while preserving their land for future generations.

The information collected is for research purposes and strictly confidential.

Does the household consent to provide information Yes ( ), No ( )

Farmer type	

General household information

Date (dd/mm/yyyy)	
Country	India
District	Bihar
Sub Location	Samastipur
Village	
Name of household head	
Name of respondent	
Gender of respondent	
PhD supporting	
Language used in interview	

1) Household composition and off-farm activities

1

The household include the people who live and share meals **at least one season per year.** Members who live somewhere else and only come to visit and bring money are not household members.

Also record permanently employed workers.

Characterise main activities of all hh members >= 16y.

Please remember to capture remittances in form 13 of those members who live away from the household.

				Hh member main activities, on-farm and off-farm (tick one for each season)										
				Zaid (Spring season)			Kharif (Monsoon season)			Rabi (Winter) season				
	Position in hh (code)	Age [y]	Gender (code)	on-farm, farming	off-farm	non-active	on-farm, farming	off-farm	non-active	on-farm, farming	off-farm	non-active	Off-farm work (code)	Notes
HH1														
HH2														
HH3														
HH4														
HH5														
HH6														
HH7														
HH8														
HH9														
HH10														
HH11														
HH12														
HH13														
HH14														
HH15														

Position: 1- head, 2- husband/wife, 3- son/ daughter, 4- son/daughter in law, 5-father/mother, 6-grandchild, 7-sibling, 11-permanently employed worker, 991-other, specify. **Gender:** 1-male, 2-female

Off-farm work: 1-agricultural (off-farm), 2-non-agricultural labour (off-farm), 3-regular employment, government ,4-regular employment, privat formal, 5-regular employment, informal, 6-self-employed (no employees), 7-business (with employees), 8-student, 9-mitigation, 991-other

How much do you earn per month from the farm

[__]Less than 2000 [__] Between 6000-10000

[__]Between 2000-6000 [__] More than 10000

From outside income, how much is this from:

Pension Off-farm jobs Subsides Remittance

[__ __] [__ __] [__ __] [__ __]

How much do you receive from outside sources

[__]Less than 2000 [__] Between 6000-10000

[__]Between 2000-6000 [__] More than 10000

Always use a drawing to clarify plots and crops with the responding farmer.

2

Basic structure

How much land area do you own? [katta]	
How much land area did you cultivate over the past year? [katta]	
In how many plots did you divide this land? (plot = same location & same crop pattern over the year)	
How many crops did you grow during the past year?	

How long have you been farming for? ____years and _____generation

How was this land inherited? (Start from grandparents)

Detail **all crops in all plots per season (plot = same location and same crop pattern over the year; up to 20)**.
Also include ponds, tree-plots and grazing areas managed by the household.

This calendar will help you in form 3 to specify crop-seasons.

Plot:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Area ( )																					
Type of land (code)																					
Irrigated areas (Yes or No)																					
distance to home [m]																					
ownership status (code)																					
Spring (Zaid)	crop																				
Kharif (Monsoon)	crop																				
Winter (Rabi)	crop																				

Ownership status: 1-owned, 2-rented, 3-shared, 991-other. **Type of land:** 1-High land 2-Low land
Crop: Cereals 11-Maize, 12-Wheat, 13-Paddy-rice (irrigated), 14-Paddy-rice (rainfed) **Pulses** 21-Common bean, 22-Green gram (moong bean), 23-Faba bean, 25-Soya bean, 26-Pigeon pea, 27-Chick pea, 28-Pea, 29-Lentils, 39-Other pulse, **Roots & tubers** 41-Potatoes 49-Other root crop, **Vegetables** 51-Onions, 52-Tomatoes, 53-Traditional vegetables, 55-Spinach, 56-Cabbage, 57-Carrot, 58-Pumkin, 59-Cauliflowers, 61-Koriander 69-Other vegetable, **Oil seeds** 71-Sunflower**,**72-Mustard, 73-Linseed, 79-Other oil seed, **Fodder** 84-Clover, 85-Lucerne, 86- Grass land, 88-Sesbania, 99-Other fodder crop, **Cash crop** 101-Sugar cane, 102-Tobacco 109-Other cash crop, **Fruits** 112- Papaya, 113-Guava, 114-Mango, 115-Orange, 116-Lime, 117-Banana, 122-Apple, 123-Litchi, 124-Melon, 125-Strawberry, 129-Other fruit, **Intercrop** 131-Intercrop 1, 132-Intercrop 2, 133-Intercrop 3, 134-Intercrop 4, **Aquaculture** 141-Aquaculture fish (salty water), 142-Aquaculture fish (fresh water), 143-Aquaculture prawns, 144-Aquaculture shrimps, 149-Other aquaculture, **Wood & fodder trees** 151-Eucaluptus, 152-Pine, 169-Other tree,   991-Other 992-Fallow, 993- not utilised by this houeshold

Crop Name	**HH %**	**Market %**	**Feed %**	**Fuel %**

Livestock		**Market %**
Cows #		
Buffalos #		
Goats #		

CSA Technologies	Are you familiarized with? (Yes/No)	Ask these together: Which ones do you use in your farm? (Select)	What are the main benefits from this practice? (Classify)	What are the major constraints? (Classify)	Did you use any of these practices in the past and now you don't? (Select)	Would you like to introduce a new practice? Which one? Why? (select; classify from benefit list)
Land laser levelling						
Raised bed planting						
Crop Diversification/Rotation						
DSR (rice)						
ICT-based agro-met services						
index-based insurance						
stress tolerant crops and varieties						
irrigation schedules (wheat)						
agroforestry						
Nutrient Expert decision support tools						
GreenSeeker						
residue management						
legume catch-mulching						
zero tillage						

List 3 most important practices	What sources of information did you consult?	Who took the initiative?	Who does it regularly?	would you introduce it again? What would have to change?	What would have to change?

BENEFITS *1 Increased yield 2 Better soil fertility and structure, 3 Less risk related to drought, 4 less risk related to flooding, 5 better food security, 6 Better income or more sources of income, 7 Less labour, 8 Less soil erosion, 9 Better soil moisture, 10 better access to water, 11 better access to manure, 12 better access to fertilizer, 13 better access to cover crop, 14 better access to livestock feed, 14 forestry products (wood, fruits, etc), 15 Environmental services (rain, shadow, temperature regulation, biodiversity), 16 Better livestock production, 17 Better livestock nutrition, 18 Disease/pest prevention, 19 Better product quality, 20 Less costs, 21 Easier or safer income access, 22 Insurance for crop losses, 23 Production diversification, 24 Less risk of loss for crop and livestock, 25 Better wellbeing, 26 No perceived benefit, 27 other-specify.* ***CONSTRAINTS*** *1 Less yield, 2 hard to get materials, 3 more labour requirement, 4 higher costs, 5 more pests/diseases, 6 poor quality product, 7 high initial investment, 8 no market for products, 9 higher risk for livestock/crop losses, 10 higher risk for financial loss, 11 lower soil fertility, 12 higher weed infestation, 13 reduction in arable area, 14 presence of dangerous animals (pigs, cows), 15 no difficulty observed, 16 other (specify)* Sources: CSA Adoption: Peterson, 2014

CHALLENGES AND VISION

Lets look at your farm from a time perspective, could you think about the hardest situations you have faced, the ones you are facing and you will face?

Rank the answers of farmers according to the topics, 1 being the most important one. Write farmers explanations below.

Type of challenges	**Past 5 years**	**Present**	**Future**
Input (increase creased cost/use)			
Market (price, access, processing)			
Labour related			
Crop problems (Low yields, health, grain size or variety),			
Farm management (machinery, technology, skills)			
Household decisions (farm succession, health/death, etc)			
Regulation changes (subsidies, taxes, restrictions)			
Higher cost for land			
Climate change (scarcity of water, increase in temperature)			
Other (Specify)			

Write here the explanation given by farmers.

Past 5 years:

Present:

Future:

How do you see your future farm?

Please make sure farmers address the different topics.

Checklist of topics		
Crop/livestock composition		
Use of technologies (irrigation, machinery)		
Labour		
Farm size/ownership		
Family participation, succession		

What part of your farm are you most proud of and why?

DECISION MAKING: FACTORS AND RELATIONSHIPS

Now we will ask you different situations that may have occurred in Bihar in the recent past or that might occur in the future. We want to know how you have changed or would change the cultivation of the different crops throughout the different seasons.

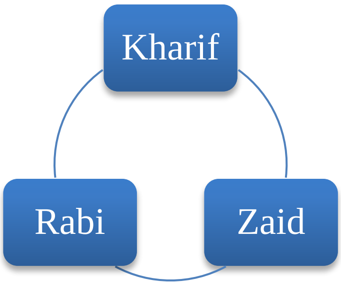
Mark with signs (+,-,=) accordingly increase (+), decrease(-), doesn't affect (=) or not applicable (NA).															
How do …. Influence the cultivation of….	**Crops**														
	Rabi						**Kharif**					**Spring (Zaid)**			
(Fill in crop names according to farm)															
Increased market price															
Higher input cost (e.g. fertilizer, herbicide, machinery)															
Higher seed cost															
Decrease household income															
Larger household size															
Decreased labour availability															
Bigger land availability															
Negative social pressure (e.g. neighbours, beliefs on tobacco)															
Increase in Rainfall															
Better soil nutrients															
Better soil moisture or irrigation															
Removal of subsidies															

Please rank the most important crops according to the following:

	Easiest to sell	Most important for household consumption	Taking most of the labour	Most important for soil quality	Most expensive one	Most profitable one
1						
2						
3						
4						
5						

CLIMATE CHANGE

Use this cycle as a reference to see changes in climate throughout the different seasons.



Have you perceived any changes in the past 5-10 years in climate. Please consider the following:

Aspects	**Changes**
Planting season	
Wind	
Rainfall	
Temperature	
Crop performance (diseases, pest, yield)	
Livestock (health, yield)	
Other	

Important climate events in the region with year

Impact of changes in the region *(Address Landscape, Use of water, Economy, Social structure)*

Have you thought about strategies to face this climate changes in the future? *(Write where they correspond).*	How could CIMMYT and BISA support you in facing these changes?
Crops:	
Livestock:	
Area:	
Diet:	
Water use:	
Farm Technology:	
Labor:	

Annex 2- CIMMYT farm typology description

Type of farmer	Land Size	Livestock heads	Mechanization level	Crops and livestock income
Part time	Median 1.1 Ha of land,	1		30% crop goes to the market. Diversified (3 cereals, vegetables and oilseed). Off-farm employment.
Well endowed	Median of 2 Ha of land and	2	Highest mechanization level.	Full-time and market-oriented farmers, with medians of proportion of income from crop (60%) and livestock activities (30%). Diversified (3 cereals, vegetables and oilseed). 50% crop goes to the market.
Small-scale crop and livestock	Median of 0.6 Ha of land, sometimes rented land.	High stocking rates (median of 2 animals on 0.4 ha), intensive use of crop residues for animal feeding (75 % as fodder), and the highest proportion of income coming from livestock activities (median of 27.5 %).	Relatively high land pressure with low mechanization level.	Diversified crop: 3 cereals, for household consumption. 40% crop is income.
Medium Scale	Median of 1.2 Ha.	1 herd.	It is the group with most proportion of land dedicated to rice followed by wheat. Maize is not present in their cropping systems.	Livestock for home consumption, not source of income. With income dependent on crop produce sold (a median of 70%).
Resource poor agricultural workers	Median of 0.3 Ha.	Highest pressure on land (a median of 28.2 adult equivalents per Ha). Livestock is not present or not important in this group and most crop residues are either sold or used for fuel.	Lowest level of mechanization.	Cropping systems of this group are exclusively dedicated to rice and wheat food staples for home consumption. Most of the income of this group comes from off farm work, mainly as agricultural workers.

Annex 3- Details of feedback session with farmers.

The 25 farmers were divided in two groups: farmers in the first session cultivated more than 2 ha. They hired labor from outside and were mainly profit oriented. It included 5 well-endowed, 2 part-time and 1 small-mixed vegetable farmer. The main objectives in FD were therefore: maximization of operating profit and minimization of labor input. Farmers in the second session were farmers with cultivation area of less than 2 ha. They used family as labor source; had 40% or more off-farm income and some of them received a regular income from milk. It included 5 resource-poor, 5 mixed livestock and 3 part-time and 4 small-mixed vegetable farmers. The objectives in FD were to maximize Household (HH) Food security, maximize profit and maximize livestock efficiency (Figure 18).

Figure 18. FD Session with farmers. All content was orally translated to Hindi, images considered literacy aspects.

This session design considered that not all farmers were literate so it prioritized visual symbols with the least amount of written information as possible, Table 16 shows topic description. Figure 19 shows the nutrient cycle presentation, images included pictures from their current crops and systems. Figure 20 is an example of the different scenarios shared with farmers. It considered four aspects: HHFS, water saving, profit and soil fertility. Five farms were modeled, one of each type. The scenarios shown are possible optimizations with different trade-offs. Farmers took a handed printout at the end of the session to take home and suggested to share this information with five other people to create a network of information diffusion. In addition, the BISA institute showed farmers the different CSA Technologies.

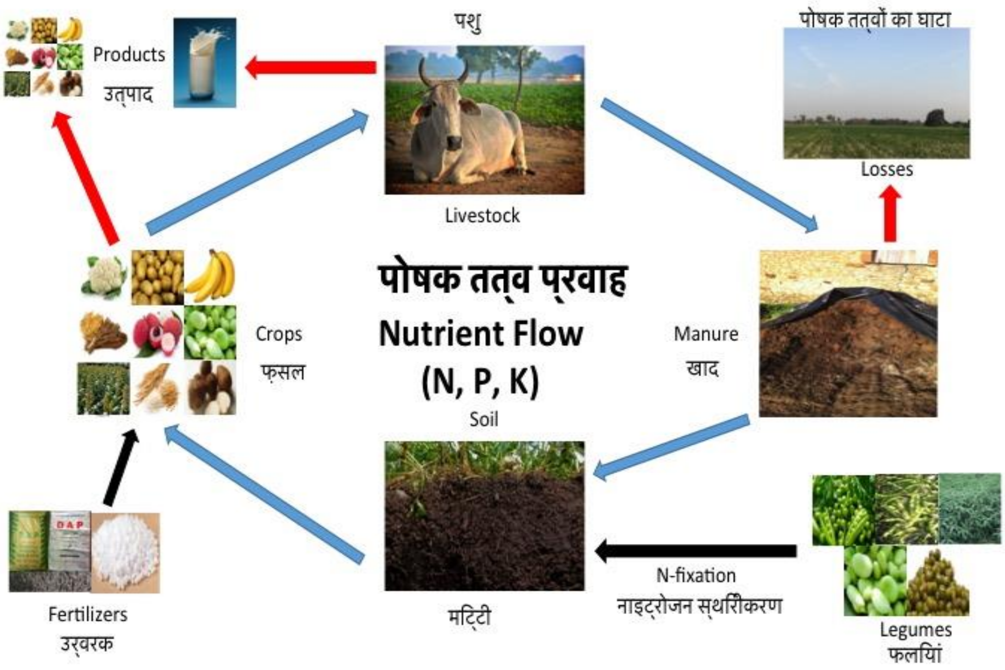


Figure 19. Representation of the farm nutrient cycle, terms translated to Hindi.

The cycle has four components Livestock, Manure, Soil and Crops. There are losses through volatilization and leaching and when products are taken out of the farm (Red arrows). Other inputs bring nutrients such as legumes (N-source) and Fertilizers (N-P-K source). Nutrients flow within the farm through different practices.

Table 16. Feedback session topic description

Topic	Content description
Feedback on positive findings about farming systems	Importance of diverse systems and food security, successful histories of farmers (those who had been able to improve their livelihoods with agriculture), satisfactions of growing their own food at lower prices than the market. Meaning of farming as a family activity. Summary of challenges and overview of session. Farmers as decision makers and leaders with in their community.
FD Nutrient Cycle	Explain how in farms nutrients interact and leave or come in the cycle.
Manure management	Address the importance of improving the manure heap by covering it, adding straw.
N-fixing crops	Share an overview of the legumes that are locally grown and their role as N-fixers.
Water saving crops	Showed different water requirements of crops in the three seasons.
Land heritage	Address land heritage as a risk for farm management and open discussion for other alternatives
First group farmers	Balancing crop areas. Consider the influence they have on neighbors and motivate them as drivers of change.

	Aspects to consider when producing seeds for sell to neighbors: yield variations due to low seeding technologies.
Second group farmers	Balancing crop areas, consider mung bean into the cropping system.
	Criteria for selecting seeds when buying from neighbors.
	Importance of networking for improving community machinery.

Figure 20. Five scenarios (Situations) explored with FD. The three cropping seasons are: Rabi, Zaid and Kharif. The last four columns are the objectives or possible trade-offs: household food security, water saving, profit oriented and soil fertility. Meeting the objective shows happy faces, a cross on top symbolizes a trade-off. Crop pictures are: wheat, tobacco in Rabi. Mung mean and vegetable and maize, rice in Kharif, fruit crops are lychees and mangos.

Figure 20 presents five different shared scenarios (situations) with the farmers, the objective was to see how trade-offs are present in the farms and how different cropping patterns support different outcomes:

1. The present farm is shown with 100% ownership of land, wheat-fallow-maize system, HHFS and Water is met.
2. A possible future farm that could involve having a larger area of land to be able to secure HHFS by growing a protein crop (mung) and still have wheat (HHFS) and maize (cash), this implies a trade-off with water.
3. Focusing on cash, the model suggested growing only tobacco, maize and vegetables but the trade-off was soil fertility at the expense of HHFS and Profit.

4. Balancing water and HHFS: the model suggested growing wheat, mung and rice at the trade-off of water, but ensuring HHFS and better nutrient balance.
5. Having a low demanding water cropping system: the extreme scenario entailed growing lychee and mango only for water saving and profit.

Annex 4- Additional information from questionnaire for FCMs

To understand crop selection within farms, a crop rating exercise was conducted in the interview. Figure 21 shows the score for all types of crops. Removal of subsidies and increase in rainfall did not have an influence, while increased market price promoted growing all crops and negative social pressure (understood as other neighbors/community stopped growing the crop) decreased the crops. Furthermore, analysis per crop use shows that cash crops are more sensitive to increased market price, negative social pressure, and increased land availability. Household (HH) crops are more sensitive to increase in market price, larger HH size, negative social pressure. Mixed crops are influenced by negative social pressure, increased market price. Cover/fuel crops are equally influenced by increased market price, bigger land availability, better soil moisture, higher input cost, decreased HH income, higher seed cost, negative social pressure, better soil moisture or irrigation (Figure 22).

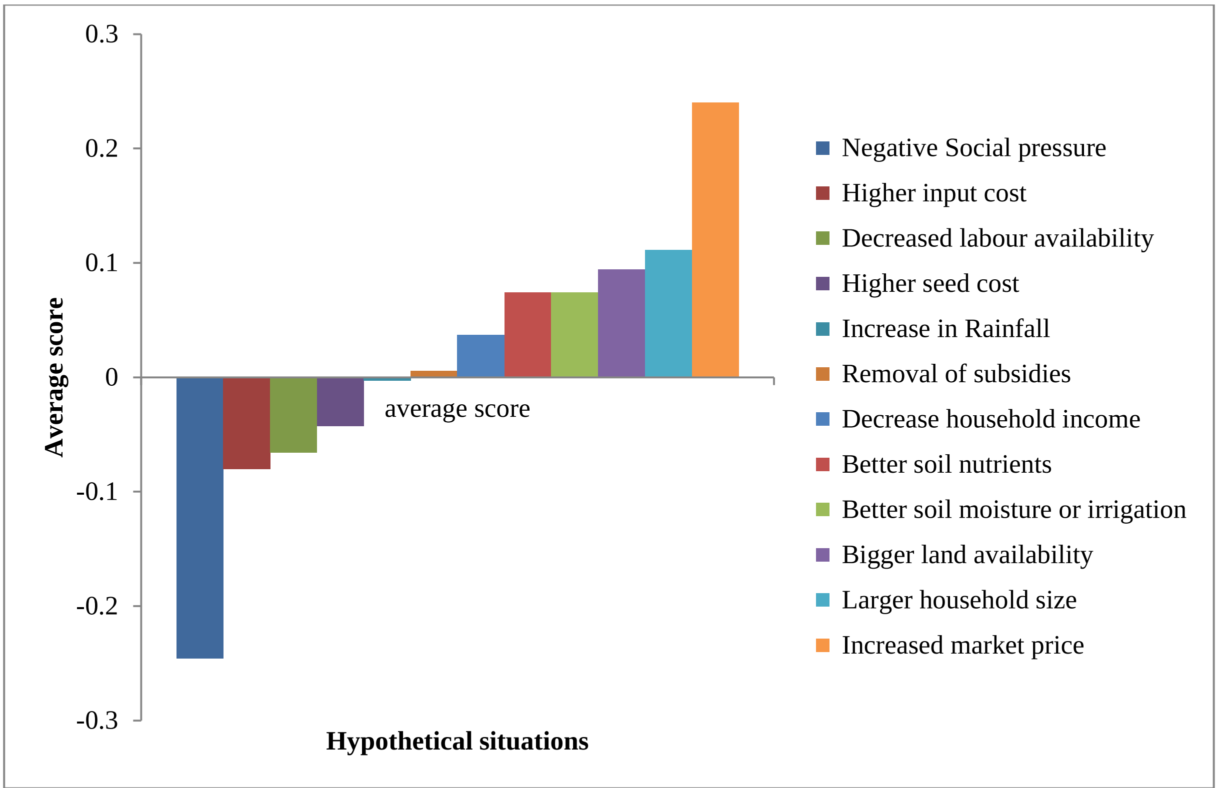


Figure 21. Hypothetical situations rating for crop selection in farms[1].

Note 1. Farmers were asked what would happen to "X" crop if "Hypothetical situation", if it increased score was 0.5, if it decreased it was -0.5 and if there was no influence it was rated as 0. Averaged score is the mean punctuations for all crops in each aspect.

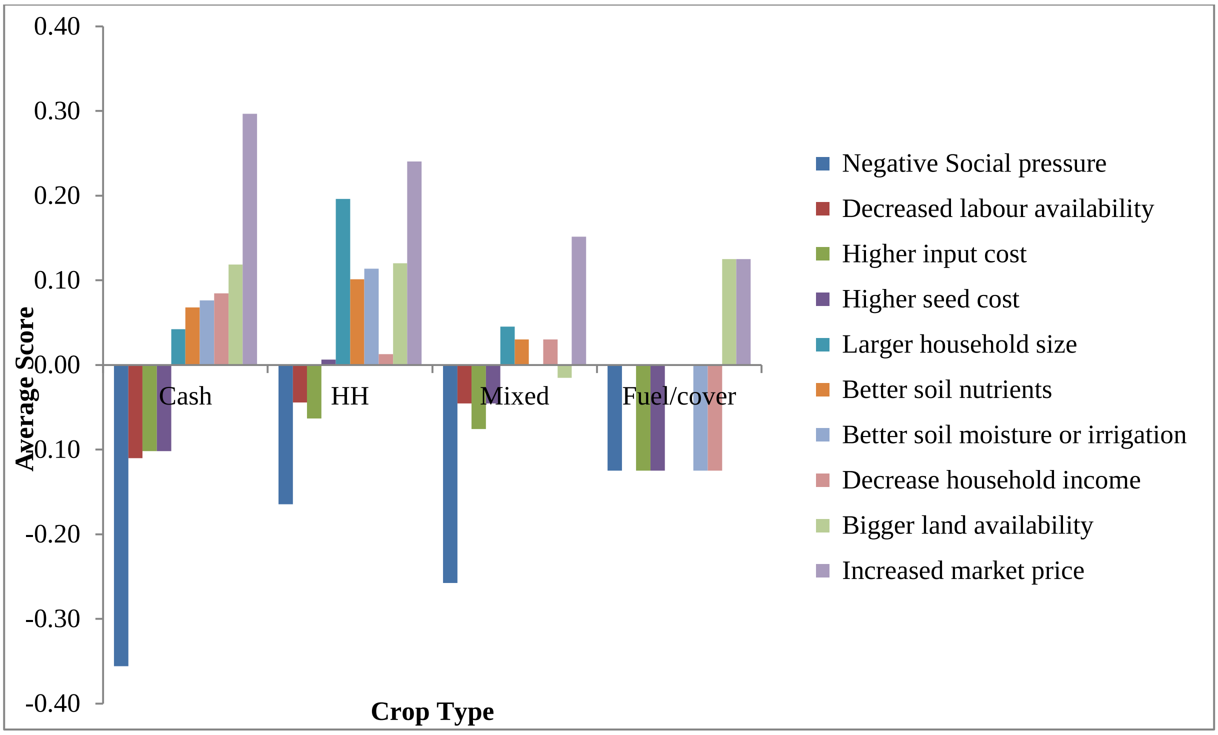


Figure 22. Hypothetical situations rating according to crop type[1].

Note 1. Farmers were asked what would happen to “X” crop if “Hypothetical situation”, if it increased score was 0.5, if it decreased it was -0.5 and if there was no influence it was rated as 0. Averaged score is the mean punctuations per crops type in each aspect.

Additionally, if there was more soil moisture or better irrigation in Kharif, rice would be preferred by all farmers over maize (Figure 23). If there was market price increase cash crops like maize, yam and the mix crops like vegetables and feed crops would be increased (Figure 24).

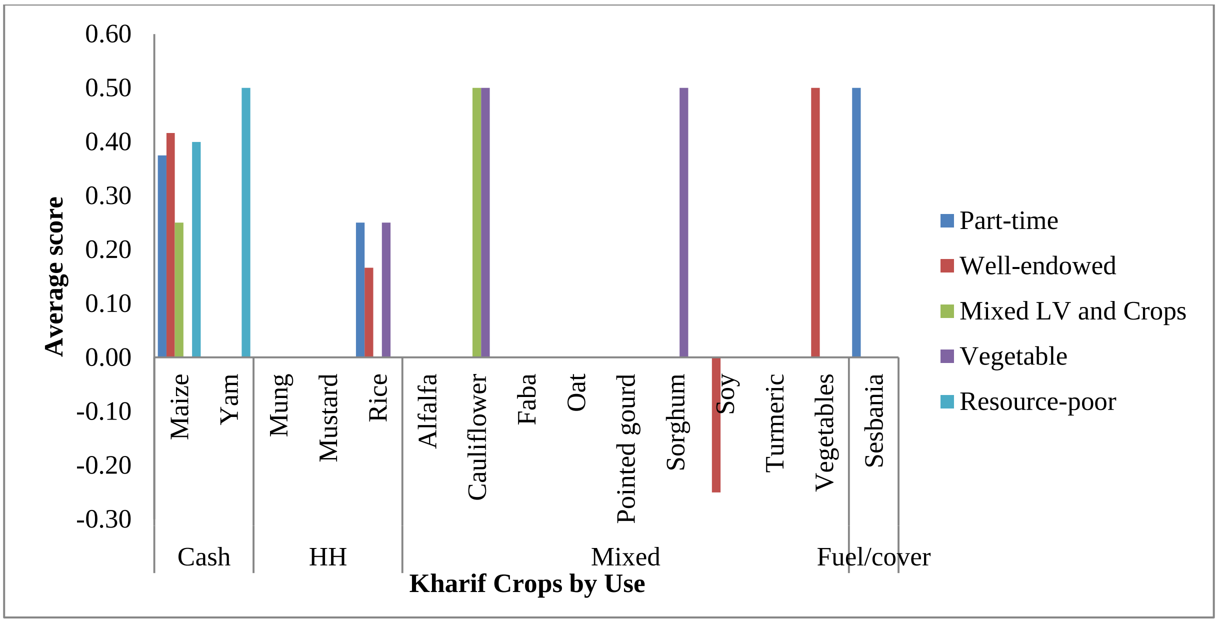


Figure 23. Crop preferred by farmers if there was improved irrigation in Kharif.

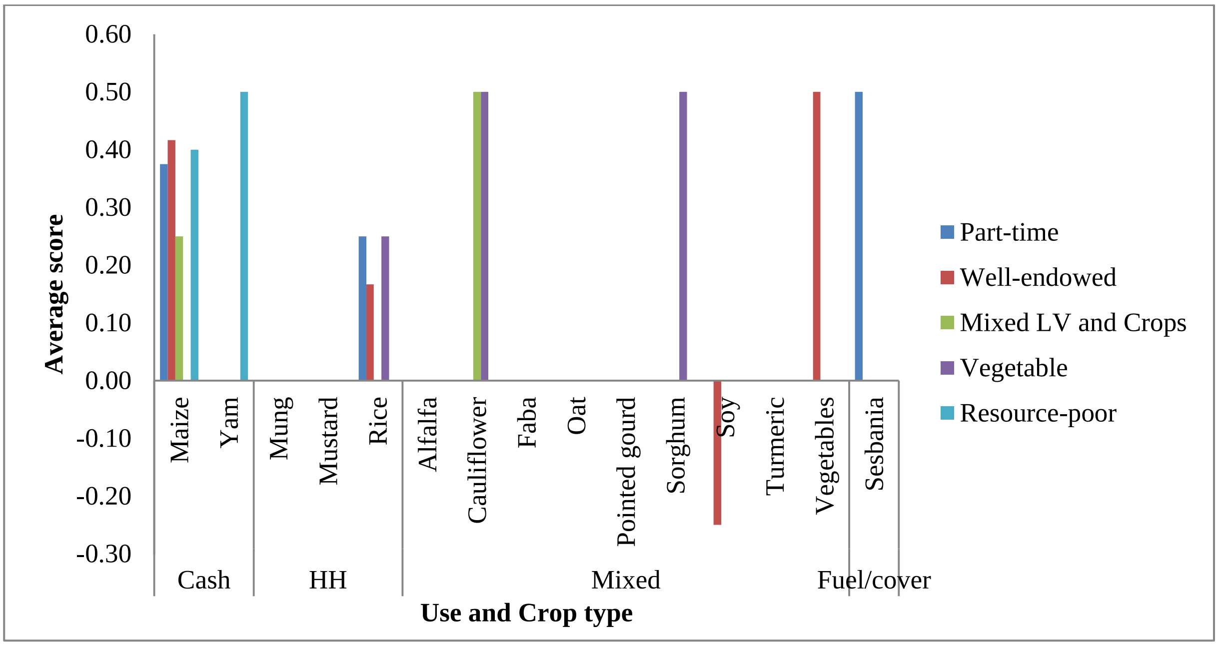


Figure 24. Crop preferred by farmers if there was price increase.